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AN INVESTIGATION OF THE LOSSES IN POWER TRANSMISSION AND AN ESTIMATE OF THE INSTALLATION AND MAINTENANCE OF AN ELECTRICALLY DRIVEN PLANT AT THE JANESVILLE MACHINE COMPANY

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A Thesis submitted for the Degree of

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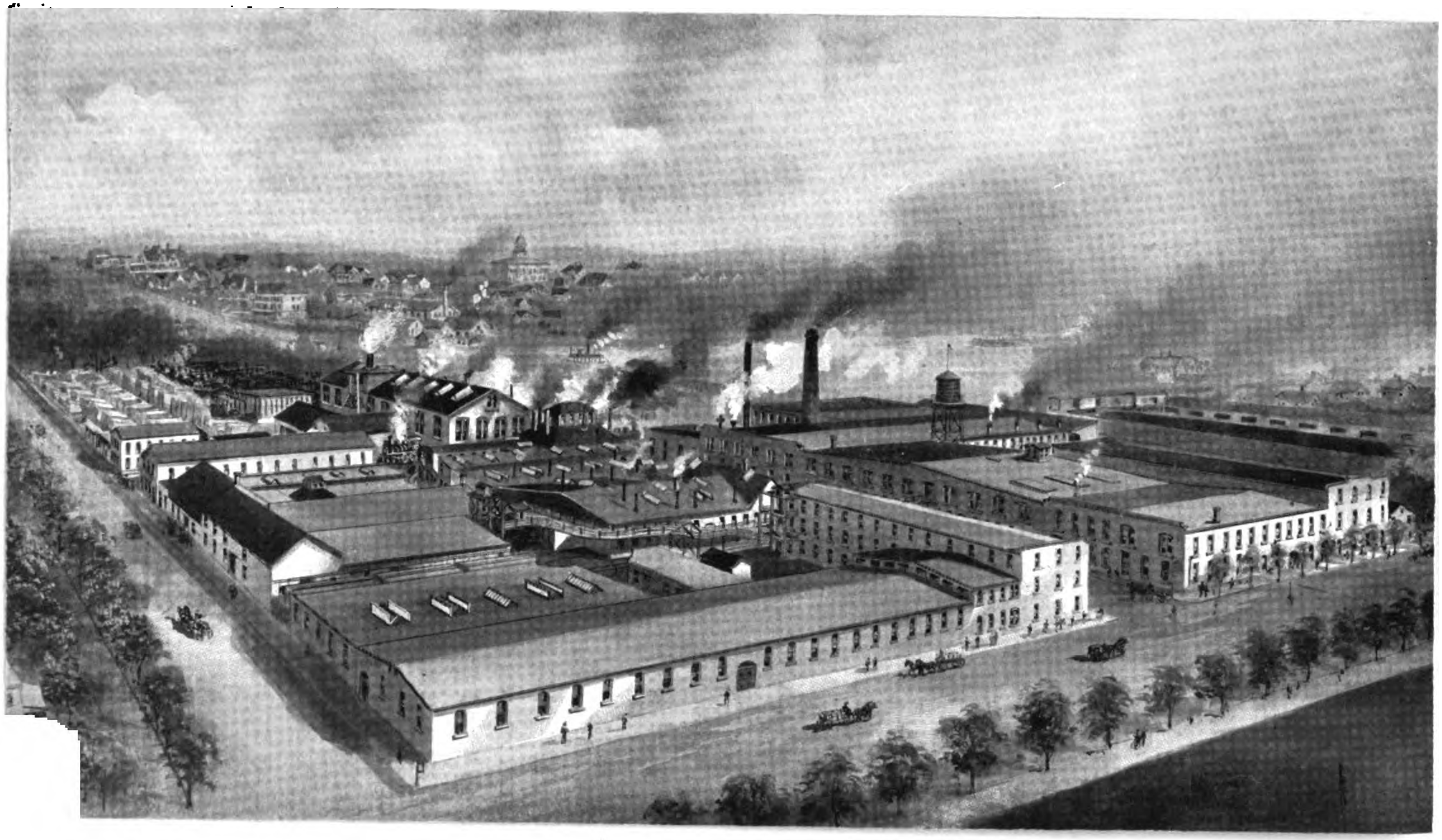
1903



Bird's-eye View of Janesville Machine Company.

TABLE OF CONTENTS.

1. General Introduction 1
2. Description of Plant 5
3. Boiler Trials 12
4. Dimensions of Scotch Marine Boiler 16
5. Data and Results of Scotch Marine Boiler Trial . . . 23
6. Discussion of Results of Scotch Marine Boiler Trial . 26
7. Conditions in Boiler Room 31
8. Dimensions of "United States" Boiler 33
9. Data and Results of "United States" Boiler Trial . . 37
10. Discussion of Results of "United States" Boiler Trial 37
11. Engine Test 41
12. Description of Engine 47
13. Report of Engine Test 52
14. Curves showing Variation of I.H.P., etc., during the day 53-55
15. Indicator Cards showing Performance of Engine during the day 56-59
16. Indicator Cards showing Friction Load 60
17. Conclusion to Engine Test 61
18. Tests of Separate Machines; Introduction 63
19. Tests of Separate Machines, in Foundry 68
20. Tests of Separate Machines, in Blacksmith Shop . . . 75
21. Tests of Separate Machines, in Plow Shop 84
22. Tests of Separate Machines, Wood Shop 94
23. Tests of Separate Machines, Machine Shop 108
24. Tests of Separate Machines, Warehouse 116
25. Results of Separate Machine Tests 123
26. Installation of Motors, Introduction 123
27. Installation of Motors in Foundry 127
28. Installation of Motors in Blacksmith Shop 128
29. Installation of Motors in Machine Shop 129
30. Installation of Motors in Plow Shop 129
31. Installation of Motors in Wood Shop 130
32. Installation of Motors in Warehouse Machine Shop . . 131
33. Estimate of Cost of Installation and Maintenance of Electric Drive 133
34. Advantages of Electrical over "shafting and belting" method of transmission . .136
35. Appendix I, Motor Losses 138
36. Appendix II, Calibration of Instruments 140

AN INVESTIGATION OF THE LOSSES IN POWER TRANSMISSION AND AN ESTIMATE OF THE INSTALLATION AND MAINTENANCE OF AN ELECTRICALLY DRIVEN PLANT AT THE JANESVILLE MACHINE COMPANY.

Introduction.

The Janesville Machine Company, located at Janesville, Wisconsin, manufactures agricultural implements, as plows, seeders, mowers, cultivators, harrows, listers, etc. They have been running for many years and have grown from a small concern to the present large proportions. As the business grew, building after building was added and, from an examination of the plant, one comes quickly to the conclusion that these buildings were erected without much consideration for economy in power transmission. There are many long shafts, one 112 feet long, running under the blacksmith shop, while another, 235 feet long drives the machinery in the warehouse machine shop. The long shaft mentioned first is driven by bevel gears, probably fifteen years old and quite badly worn.

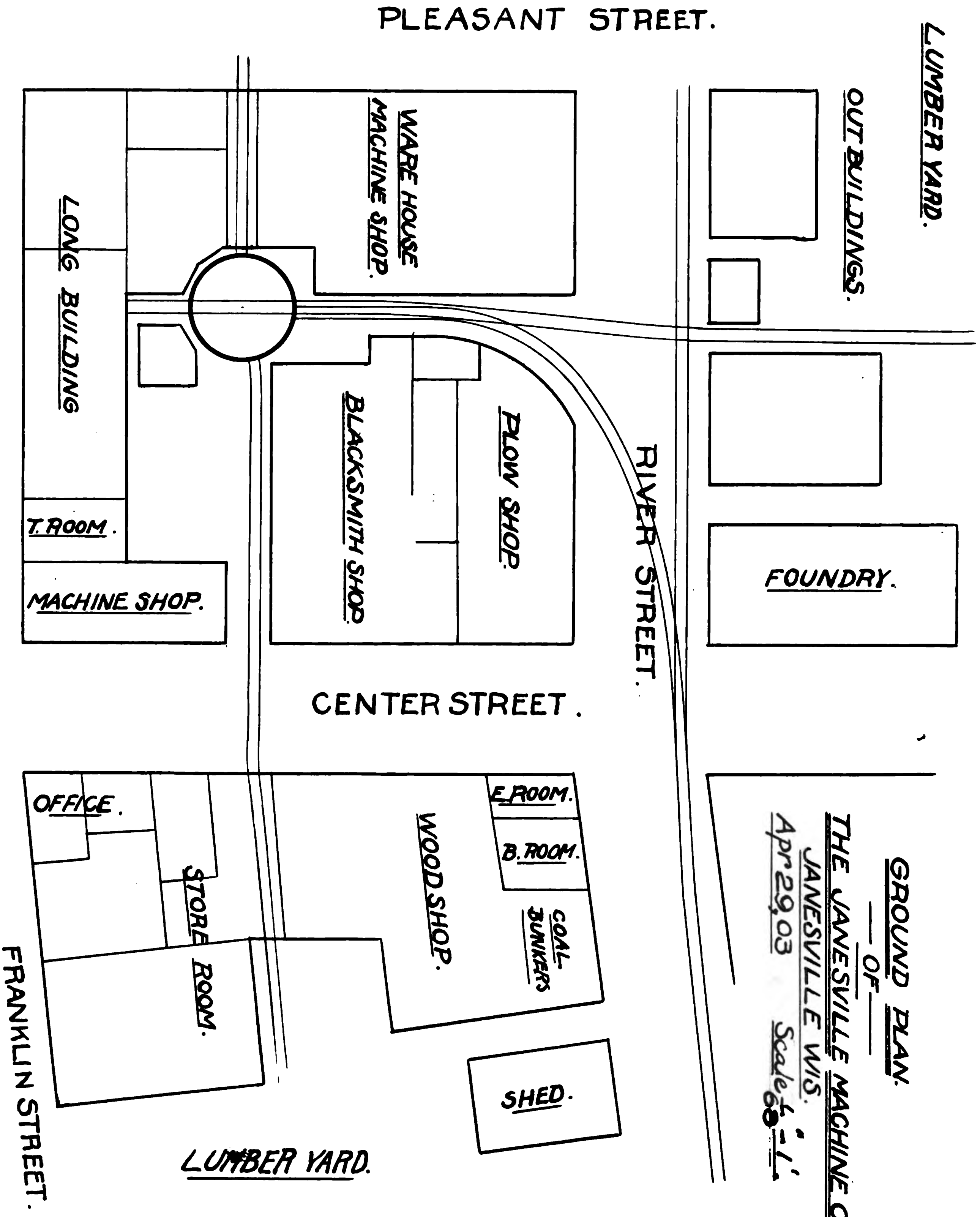
The losses in power transmission are consequently large and it was one of the objects of this thesis to investigate these losses. Another object was to determine the cost of installing and maintaining an electrically driven

plant and making an estimate of the probable saving in a year's time. To do this, a motor was used to determine the power consumed by the different machines or departments.

The data for working up this thesis were obtained from December 25, 1902, to January 9, 1903, when the shops were exceedingly busy, the engine and boilers probably doing the maximum work of a year's run. Not only were the boilers called upon to furnish steam for the engine but also for the heating purposes of the entire establishment.

It was the intention of the authors of this thesis to determine the exact average working conditions of the plant, and not its performance under the best possible conditions.

WAREHOUSE — GROUND FLOOR



PLEASANT STREET.
LUMBER YARD.
OUT BUILDINGS.
WARE HOUSE
MACHINE SHOP.
LONG BUILDING
T. ROOM.
MACHINE SHOP.
BLACKSMITH SHOP.
PLOW SHOP.
RIVER STREET.
FOUNDRY.
CENTER STREET.
OFFICE.
STORE ROOM.
WOOD SHOP.
E. ROOM.
B. ROOM.
COAL BUNKERS
SHED.
LUMBER YARD.
FRANKLIN STREET.
GROUND PLAN
— OF —
THE JANESVILLE MACHINE CO.
JANESVILLE WIS.
Apr 29, 03 Scale 1/60 = 1'

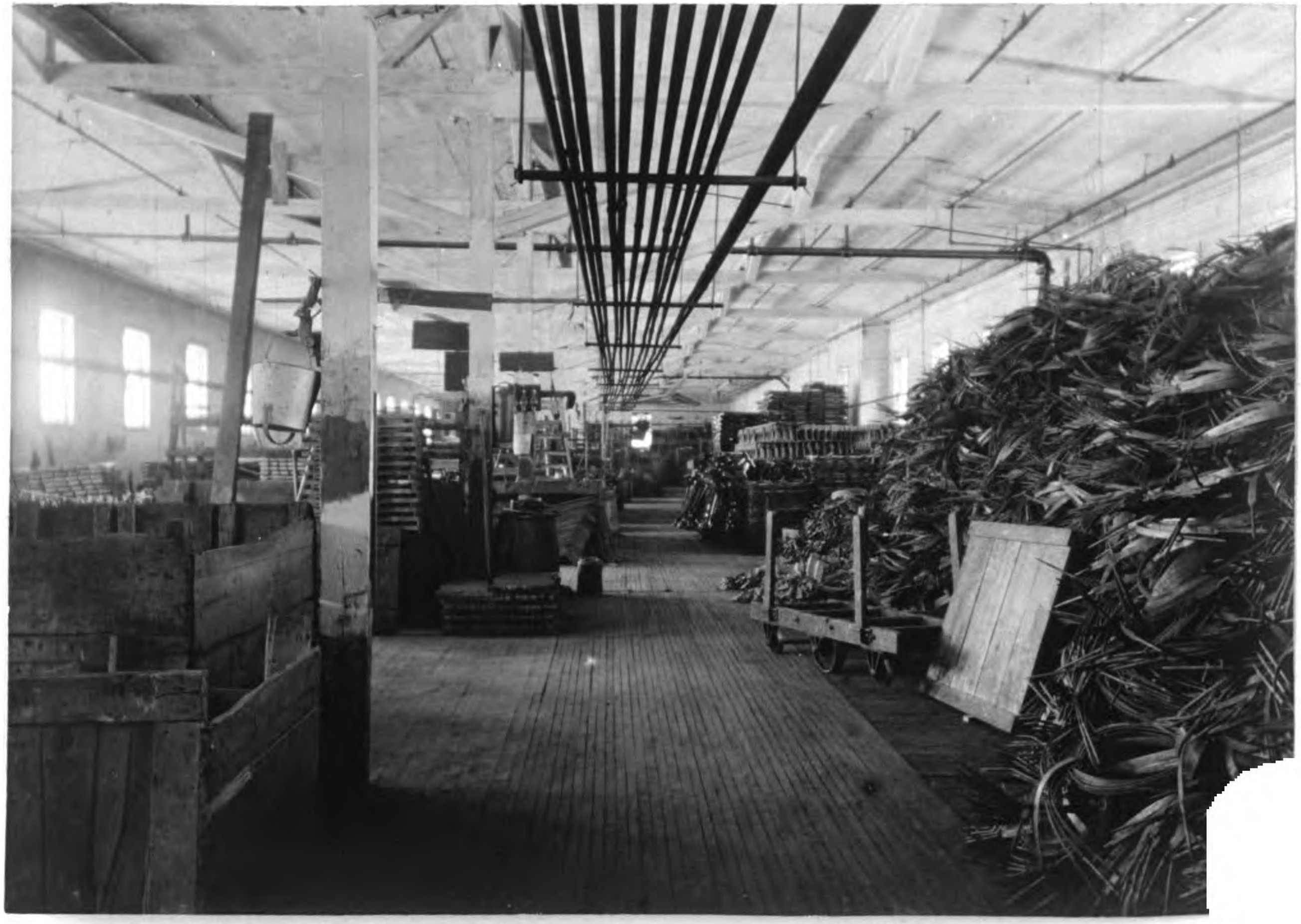
Description of Plant.

The Janesville Machine Company is situated nearly in the center of the city, the boundary lines running approximately north and south, east and west. The plant, as the accompanying drawing shows, is limited, on the west, by Franklin street, along which runs the Rockford, Beloit and Janesville Electric Railroad, on the north by Pleasant street, on the south by the Janesville Barb Wire and Nail Company's factory building, and on the east by Rock River. The plant occupies about three blocks, which necessitates a division by two streets, namely: Center and River streets, which run respectively, east and west and north and south. The railroad facilities of the Janesville Machine Company are very good. Having access to the Chicago and Northwestern Railroad by way of River street, a spur is brought around the plow shop to a turn table where the cars can be shifted either into or alongside the warehouse for loading purposes, or down the passageway between the machine shop and blacksmith shop, and thence to the wood shop, warehouse and lumber yards back of the wood shop. In this manner, the raw material and finished products can be readily handled and no delay be caused by poor railroad service. Stock and material, such as bar steel, iron, wood, coal, etc., can be readily deposited in their proper places, while the manufactur

ed product of the company can be speedily shipped to the various parts of the country.

Situated on the Rock River, the company has an exeellent means of getting rid of its waste material which can be dumped on the banks of the stream, and at the same time, extending the property, an advantage which is sought by all manufacturers. Being so close to the stream obviates the necessity of connecting with the city sewerage system, since sewerage can be readily conveyed to the stream by an inexpensive, private system.

The water supply is obtained from two sources, namely, the city water works and a well owned by the company, the city water being used as supply only in case of emergency. The water from the well is pumped to a large tank above the wood shop, where it can be distributed at a good pressure. As a protection against fire, a pumphouse with suitable pumps, has been recently installed just outside the engine room. To these pumps, is connected a system of pipes fitted with composition plugs fusible at low temperatures. This system includes both the pneumatic and hydraulic design, the pneumatic being installed throughout most of the plant while the hydraulic is used in the engine and boiler rooms and the coal bunkers. The shops are also provided with an electric system which will, in case of fire, immediately start the pumps. The company has also a private alarm bell in connec-



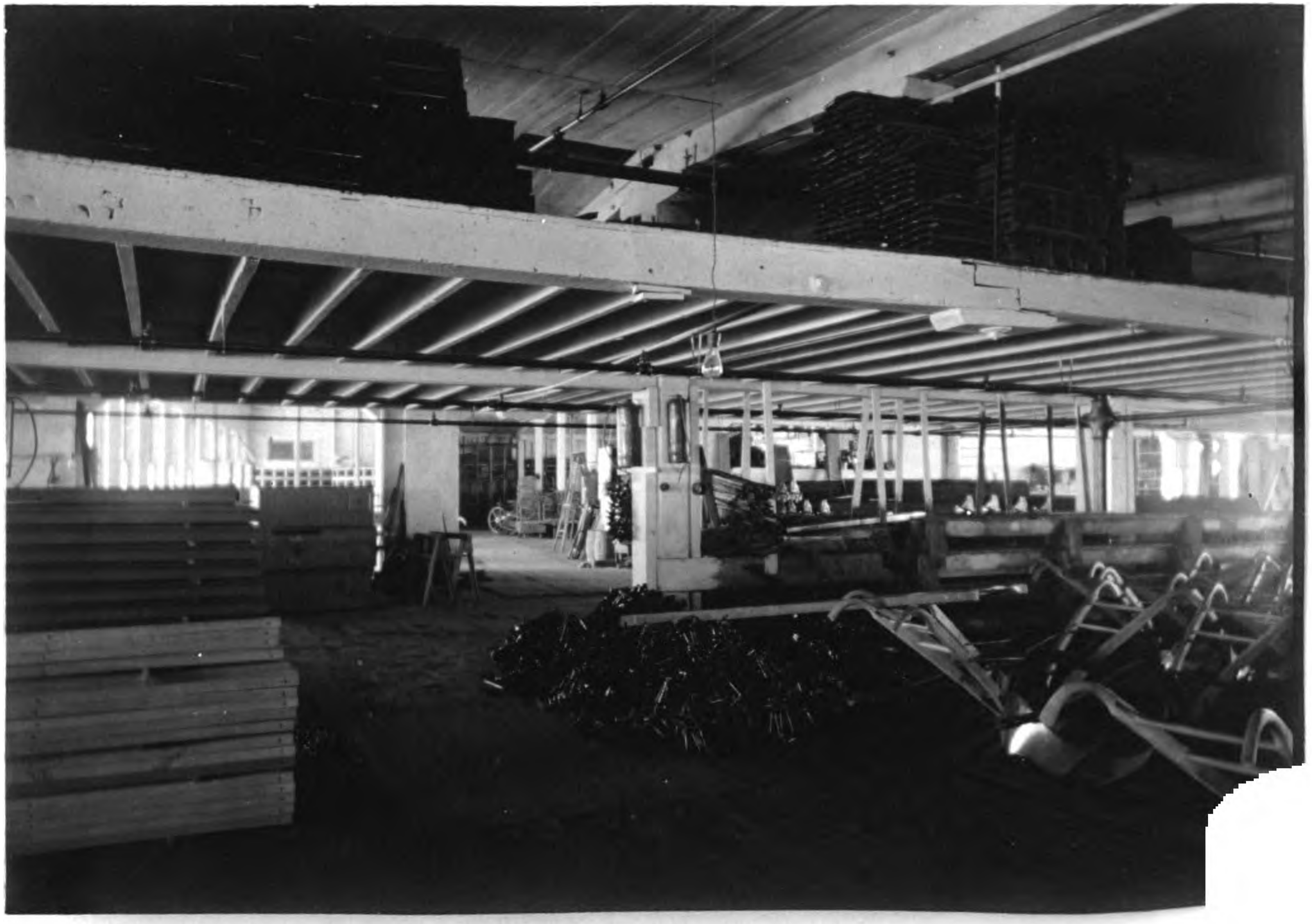
"Long Building," looking north.

tion with the city fire department, some three blocks away.

In the winter time, the plant is heated with steam, by means of a system of pipes extending throughout the plant. There are two methods used in heating: (1) One consisting of forcing air through coils of heated steam pipes; and (2) by the radiation of heat from radiators. The wood shop, paint shop and erecting room over wood shop are heated by exhaust steam from the engine, while the offices and the rest of the plant are heated by live steam which, when condensed, is pumped back to a hot well in the engine room to furnish feed water for the boilers.

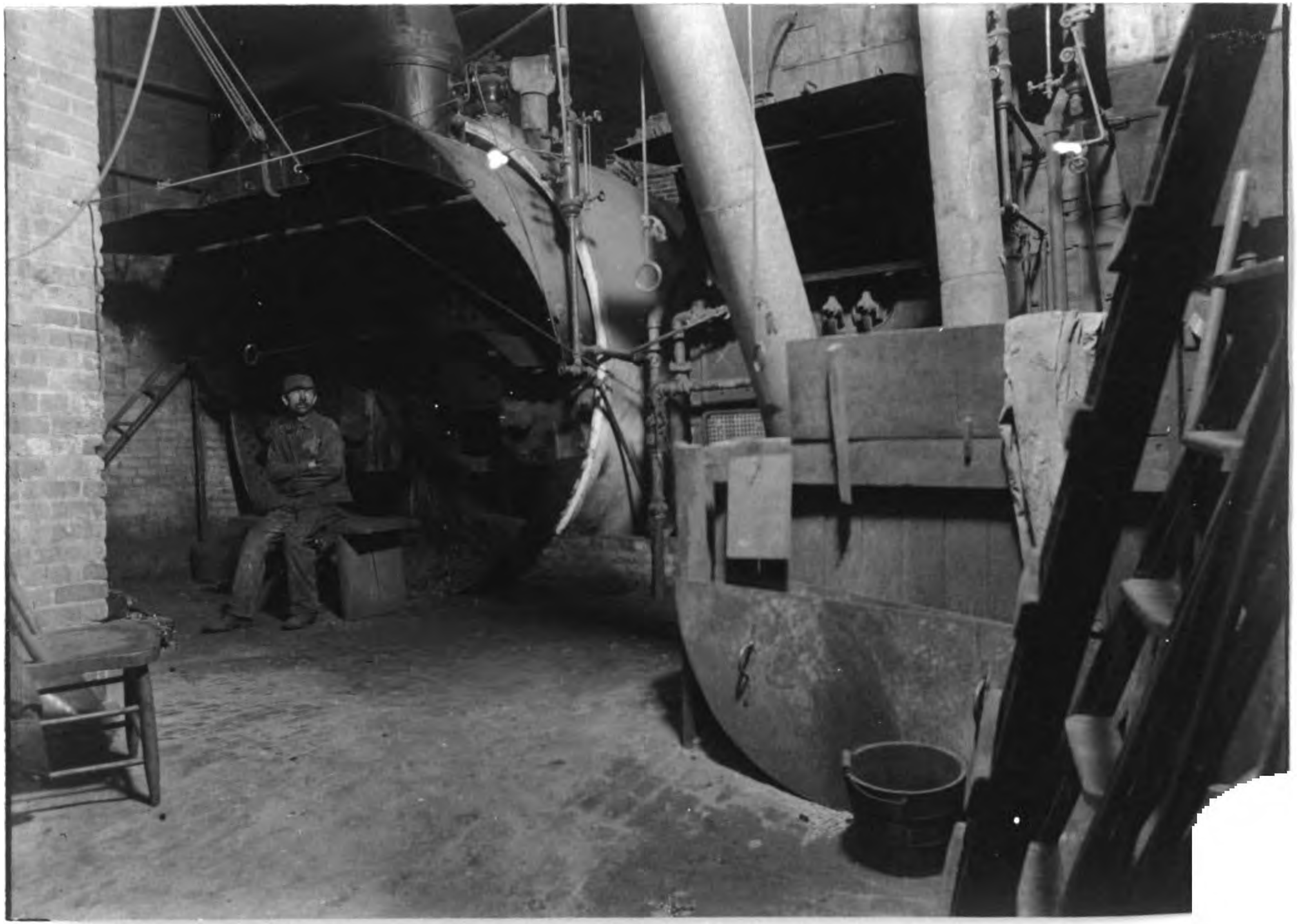
The plant is wired in some parts with an Edison three-wire system so that a direct current of 110 or 220 volts can be taken off for incandescent lamps or motors. The circuit is connected with the light and power system of the Janesville Electric Company, whose power station is located about two blocks from the plant.

As the plant of the company has grown and enlarged, new buildings have gradually replaced the old ones and new ones also added. The new buildings include "Long Building," Foundry, Warehouses, and nearly all of the buildings south of Center street while the old ones include the machine shop, blacksmith shop, plow shop and a few sheds and out-buildings. New machinery has also been added and, as the plant grew, and demands for greater output increased, it became necessary



Paint Shop.

to furnish more power and consequently a new boiler and engine were installed, the position of which can be seen from the cut on page 124.The power is transmitted to a shaft 235 feet long, from which it is taken off by means of belts to parallel shafts in the wood shop, blacksmith shop, plow shop, and warehouse machine shop, and by a rope drive to the foundry, while, in the case of the machine shop, the power is transmitted from the main shaft to one at right angles by means of a bevel gear.



Boiler Room.

Boiler Trials.

Description.

The engine and boiler rooms of the Janesville Machine Company occupy the corner facing Center and River streets, as shown by the plan of the plant on page 4. These rooms were evidently planned to accommodate a small installation, at a time, when perhaps a single man could have easily operated both engine and boiler. The situation of today is entirely different, yet the same arrangement is adhered to.

In the boiler room are three boilers, two of them old "United States" boilers of small capacity, the other a new 350 H.P. Scotch marine boiler, built by Freeman and Sons, of Racine, Wisconsin. The latter is used for furnishing power for a 300 H.P. engine, while the former are used only in the winter time for heating purposes and for power generation in case of emergency. The coal bunkers are considerably removed from the boiler room. The feed water heater, which utilizes the exhaust steam from the engine, is placed in the engine room, while the important piping which serves the boilers, forms a network in a dark space underneath the engine room. Pipes and connections are here arranged, so that either city or well water may be fed separately or together to any one or to all of the boilers at the same time. The water may be forced through the feed water heater on its

way to the boiler as is usually done, or it may be fed direct. A third source of feed water is that due to the condensed steam in the heating system. This water accumulates in a hot well under the engine room and can be fed direct to the boilers. Connected to the above mentioned piping, are four pumps, two steam and two of the plunger type.

Method and Apparatus used.

The boiler trial made upon the Scotch marine boiler was made in accordance with the standard method of the American Society of Mechanical Engineers. The trial, so far as it was practicable, was made according to the alternate method. The boiler was handled under ordinary operating conditions, as is done day by day, nothing having been done either before or during the test to change the conditions from those occuring in the regular operation of the plant. Well water was used together with the water from the hot well on the day of the trial. To obviate the difficulties involved in measuring the water from each source separately, they were forced through the feed water heater together and their combined weight taken. The apparatus for weighing the feed water consisted of three tanks, two of which rested upon platform scales supported by staging, while the third was placed beneath. The water was drawn from the heater into tank No. 1. After this tank had been filled, the water from the heater was turned into tank No. 2. While No. 2 was

filling, No. 1 was being weighed up and emptied into tank No. 3, and so on. Tank No. 3 served merely as a reservoir from which water could be pumped into the boiler. Pumps belonging to the company could not be used on account of their location under the engine room floor, so a steam pump was kindly loaned by the Janesville Street Railway Company, for the purpose of pumping the feed water from tank No. 3 into the boiler.

The coal was weighed as it was brought to the boiler room and a record kept of the same. The stack had already been tapped just above the damper and a pyrometer inserted for measuring the flue gas temperature. A Carpenter's draft tube had been placed about a foot higher, for determining the draft pressure, while still higher in the stack an opening had been made from which flue gas samples might be obtained. A throttling calorimeter was employed for obtaining the quality of the steam.

The Test.

On the seventh of January, 1903, the fires were started in the Scotch marine boiler at six o'clock a.m., in preparation for the day's run, which begins at seven o'clock a.m. and lasts until six p.m. At seven o'clock, the ash pit was thoroughly cleaned.The condition of the fires was noted, and the water level in the boiler marked. Temperature readings were taken every hour of the water entering the heater, and every half hour of the water entering the boiler and of the gases in the stack. At half-hour intervals, readings were recorded for the pressures of steam in the boiler and for the draft in the stack. Flue gas samples were obtained at intervals and immediately analysed. Calorimeter readings were taken every half-hour. Samples of coal were taken from time to time, and a final sample obtained by a system of quartering.

In concluding the trial, the water in the boiler was raised to its original level and the condition of the fires was made to correspond to that existing at the beginning of the trial. The ashes were taken from the ash pits and weighed and finally the small steam pump, whose exhaust was run out of doors, was tested for steam consumption. This was done by condensing the exhaust in a tank and noting the amount of steam required for pumping a given weight of water

into the boiler. Curves showing the variations of the readings will be found on pages 54 and 55.

Instruments.

The instruments used were:

One steam gauge,

One Orsat flue gas apparatus,

One calorimeter,

One pyrometer,

One draft gauge.

These instruments were calibrated, the tables and curves for such calibrations being found in Appendix II, page 140.

Dimensions of the boiler:

Length in feet - - - - - - - - - - 13
Outside diameter in feet - - - - 12.5

Thickness:

Shell in inches - - - - - - - -- - 25/32
Tube sheets in inches - - - - - - 25/32
Furnaces in inches - - - - - - - - 1/2

Combustion chamber:

Thickness - - - - -
Depth in inches - - - - - - - - - - 21
Diameter in feet - - - - - - - - - 10-3/4

Furnaces:

Diameter in feet - - - - - - - - - - 4-1/3
Length of grate in feet - - - - - - -8
Width of grate in feet - - - - - - - 4-1/3
Number - - - - - - - - - - - - - - - - 2

Tubes:

Inside diameter in inches - - - - - - - 3
Length between sheets in feet - - - -13
Number - - - - - - - - - - - - - - - - - -161
Spaced vertically in inches - - - - - - 1.44
Spaced horizontally in inches - - - - - 1.44

Smoke-pipe:

Diameter in feet - - - - - - - - - - - - 4
Area in square feet - - - - - - - - - - 12.56
Height above grate in feet - - - - - - 75

Bridge:

Above grate in inches - - - - - - - - - -10

Ash Pit:

Height in inches - - - - - - - - - - - - 20
Width in feet - - - - - - - - - - - - - - 4
Diameter in feet - - - - - - - - - - - - 4-1/3
Length in feet - - - - - - - - - - - - - -8
Grate area in square feet - - - - - - 69.6

Heating surface:

Area of tubes in square feet - - - 1642
Area of both furnaces in square
feet - - - - - - - - - - - - - - - - - 381.5
Effective area of combustion chamber
in square feet - - - - - - - - - - -23.8

Total heating surface in sq. ft. - 2046.8

Diameter live steam pipe in inches - - - - - 6
Diameter feed water pipe in inches - - - - - 2

Ratio of water-heating surface to grate
surface - - - 29.4

Coal used on Trial of Scotch Marine Boiler.

Gross	Tare	Net
363#	130#	233#
425	"	295
406	"	276
423	"	293
437	"	307
400	"	270
363	"	233
333	"	203
400	"	270
406	"	276
349	"	219
423	"	293
409	"	279
386	"	256
335	"	205
302	"	172
300	"	170
311	"	181
369.5	"	239.5
309.5	"	179.5
337	"	207
356	"	226
356	"	226
344	"	214
360	"	230
414	"	284
365	"	235
335	"	205
310	"	180
310	"	180
345	"	215
335	"	205
376	"	246
11,997#	4,290#	7,707 Total Net.

Feed-Water used on Trial of Scotch Marine Boiler.

Tank No. 1.			Tank No. 2.		
Gross	Tare	Net	Gross	Tare	Net
605	230	375	1047	192	855
855	165	687	707	195	513
697	230	467	433	194	239
1300	205	109	1100	195	905
1100	700	400	1200	522	678
1027	300	727	1190	294	896
1230	175	1055	890	305	585
830	165	665	820	305	515
560	165	395	700	192	508
828	165	663	690	189	501
675	165	510	947	281	666
1185	195	990	1095	193	902
635	167	468	800	238	562
820	167	653	855	194	661
748	167	581	667	193	474
973	205	768	1018	194	824
1015	165	850	835	298	537
1132	162	970	1017	220	797
797	175	622	920	264	656
765	165	600	976	195	781
879	165	714	1323	210	1113
789	259	530	1158	303	855
1130	210	920	844	200	644
1250	178	1072	1187	192	995
938	193	745	669	380	289
1050	190	860	638	278	359
901	188	713	1015	212	803
1133	580	553	1024	290	734
1097	199	898	1210	200	1010
1221	198	1023	1200	288	912
1310	202	1108	1242	193	1049
		22,677#			21,818#

Total pounds.....44,495

Temperature of Feed-Water used on Trial of Scotch Marine Boiler.

Leaving heater.

107
174
170
192
180
190
180
181
186
193
180
192
190
184
184
170
185
182
142

136
100
140
160
148
161
104

165.8 degrees average temperature Fahrenheit.

Cold.

69.5
75.
79.
79.
75.3
66.
61.5
60.7
65.7
60.5

69.2 degrees average temperature Fahrenheit.

Flue-gas temperature.

410
560
480
480
540
554
460
440
580
450

500
560
495
510
540

504 degrees average temperature Fahrenheit.

Flue-gas draft.

.25
.25
.25
.25
.25
.25
.25
.23
.25
.247
.245
.25
.25
.245
.25
.252
.25

.248 inches of water

Scotch Marine Boiler.

Result of Flue-Gas analysis.

Time	CO_2	CO	O	Total
9:30	2.0%	0.0%	18.2%	20.2%
11:	1.2	1.0	17.8	19.0
1:30	5.0	0.0	15.0	20.0
2:30	2.1	1.9	14.9	19.
3:30	4.0	0.6	----	----
5:30	4.0	0.2	----	----
Average-	3.1%	0.62%	16.5%	19.5%

Calorimeter Readings.

			Boiler Pressure		
Time	Temp.	Pres.	Gauge	Absolute	Quality
7:30	270.5	4.8	97.5	111.7	98.8%
8:00	256.	3.6	97.5	111.7	98.1
8:30	265.3	3.5	78.5	92.7	99.1
9:00	264.	3.7	82.5	96.7	98.9
9:30	262.7	3.48	72.5	86.7	99.1
10:00	264.2	3.60	79.5	93.7	99.0
10:30	258.	3.23	69.5	83.7	98.9
11:00	265.2	3.88	79.5	93.7	99.0
11:30	263.	3.52	70.5	84.7	99.2
12:00	254.	2.82	62.5	76.7	98.9
1:30	270.	4.12	92.5	106.7	99.0
2:00	268.3	3.9	83.5	97.7	99.1
2:30	266.3	3.96	86.5	100.7	98.9
3:00	266.7	4.39	86.5	100.7	98.9
3:30	Missed				
4:00	267.	3.77	81.5	95.7	99.1
4:30	260.	3.48	64.5	78.7	99.2
5:00	255.	3.44	72.5	86.7	98.7
5:30	256.	3.62	71.5	85.7	98.75
	256.3	3.71	80.5	94.7	98.93%

Data and Results of Evaporative Test.

Date of trial - - - January 7, 1903.
Duration of trial - ten hours.
Kind of furnace - - tubular corrugated.

Average Pressures.

Steam pressure by gauge, lbs. per sq. in. - - - - 80.50
Pressure of flue-gas, in. of water - - - - - - - - - 0.25

Average Temperatures Fahrenheit.

Of fire-room, in degrees - - - - - - - - - - 85.
Of steam, in degrees - - - - - - - - - - - -313.60
Of feed-water entering the heater,
in degrees - - - 69.2
Of feed-water entering the boiler,
in degrees - - - 165.8
Of escaping gases from furnace, in
degrees - - - 504.

Fuel.

Kind of fuel - - - Spring Valley.
Size - - - - - - - - lump.
Weight of coal as fired in pounds - - - - - - - - -7707.
Percentage of moisture in coal in percent - - - - - 5.8
Weight of coal dry in pounds - - - - - - - - - - - 7260.
Percentage of ash and refuse in dry coal-
- - - - - 3.64
Total ash and refuse in pounds - - - - - - - - - 264.
Quality of ash and refuse - - - fine.
Total combustible consumed, in pounds - - - - - - - 7014.

Proximate Analysis of Coal.

Moisture in percent - - - - - - - - - - - - - - - - - - - 5.8
Fixed carbon in percent - - - - - - - - - - - - - - - 49.28
Volatile matter in percent - - - - - - - - - - - - - - 40.60
Ash in percent - 10.12
Dry coal in percent - - - - - - - - - - - - - - - - - - 100.

Fuel per Hour.

Dry coal consumed per hour in pounds - - - - - - 72.60
Combustible consumed per hour in pounds - - - - - 70.14
Dry coal per square foot of grate surface per hour in pounds - - - - - 1.045
Combustile per square foot heating surface in pounds - - - - - - - 0.343

Calorific Value of Fuel.

Heat of combustion of coal in B.T.U. - - - - - - -11470

Quality of Steam.

Percentage of moisture in steam in pounds - - - - 1.07

Water.

Total water fed to boiler in pounds - - - - - -44495
Water actually evaporated, corrected for quality of steam in pounds - - - - - - -43870
Factor of evaporation - - - - - - - - - - - - - - - -1.08
Equivalent evaporation of water into dry steam from and at 212 degrees in pounds - - - 47800

Water per Hour.

Water evaporated per hour corrected for quality of steam in pounds - - - - - - - - - - - - 4387.
Equivalent evaporation per hour from and at 212 degrees in pounds - - - - - - - - - 4780
Equivalent evaporation per hour from and at 212 degrees, per sq. ft. of heating surface in pounds - - - - - - - - - - - - - - 2.26

Horse-Power.

Horse-power developed. (34.5 lbs. of water evaporated per hour into dry steam from and at 212 degrees equals one horse-power)- - - - - - - - - - - - - - - - - 134.03
Builders rated horse-power - - - - - - - - - - - - 350.00
Percentage of builders to developed horse-power - - - - - - - - - - - - - - - - - 37.16

Economic Results.

Water actually evaporated under actual conditions as fired in pounds	5.68
Equivalent evaporation from and at 212 degrees per pound of coal as fired in pounds	6.20
Equivalent evaporation from and at 212 degrees per pound of dry coal	6.57
Equivalent evaporation from and at 212 degrees per pound of combustible	6.82

Efficiency.

Efficiency of boiler in percent	57.5
Efficiency of boiler and grate in percent	55.4

Cost of Evaporation.

Cost of coal per ton of 2,000 pounds	$3.00
Cost of coal required to evaporate 1,000 pounds of water from 212 degrees	$0.264

Discussion of Results and Conditions.

During the trial 3.2 percent of ash was collected under the grate, while in the laboratory the test made upon this coal for ash showed it to contain 10.12 percent. This difference is accounted for by the smaller particles of ash being carried to the combustion chamber or up the stack by the draft.

In testing the coal for heat of combustion, a "bomb" calorimeter was used, the average of several determinations giving a value of 11,470 B.T.U. This result indicates that the coal has a very poor heating value.

The very low efficiency of the boiler is largely influenced by the low heating value of the coal. The temperature of the flue-gases remained very high throughout the day, and consequently show that there was a large amount of heat escaping up the stack. It is evident that a higher efficiency might have been obtained if this temperature had been kept down. The factor which influenced the low efficiency, more than anything else, was the low percentage of carbon dioxide maintained throughout the trial, the effect of which will be considered in detail later. During the noon hour some heat was radiated from the boiler. This item would not be large enough to appreciably alter the results, and was therefore neglected.

During shipment the pointer of the standard steam gauge, which was to be used on the test, became loose. Before the gauge was used the pointer was fastened securely. The gauge was afterward calibrated in the steam laboratory of the University of Wisconsin and the boiler pressure readings corrected in accordance with the calibration made. The calibration curve can be found on page 151.

Some difficulty was experienced in keeping the water level in the boiler up to the desired mark. This was due to the fact that the very hot feed-water destroyed the pump's suction, and constant attention was necessary to keep the pump to its work.

The calorimeter readings which were taken for the boiler trial, were read from a calorimeter placed about two feet above the engine cylinder. As the distance between the engine and boiler was only about thirty feet, and as the piping was well covered, the condensation of steam in the pipe was of practically no consequence. The high values obtained for the quality of the steam, and shown on page 55, can be placed in evidence of this fact.

The flue-gas analysis was made in a portable type of Orsat apparatus. The purpose of the analysis was to determine the percentages of carbon monoxide, carbon dioxide, and oxygen, which percentages are a measure of the completeness of combustion. With nitrogen, these three gases are the important constituents of the waste gases.

In the test only 3.1 percent of CO_2 was found to be present, in the waste gases of the furnace. This percentage is exceedingly low, since for good conditions from ten to twelve percent of CO_2 should be present. It is evident that this small percentage of CO_2 is accompanied by a great loss of heat. This is due to the fact that a large amount of air is required to furnish the necessary oxygen for the combustion of the coal, when a small percentage of CO_2 is formed than when the percentage of CO_2 is large. Over three times as much air is admitted to the furnace when 3.1 percent of CO_2 is present in the flue gas, as is admitted when ten to twelve percent of CO_2 is present. It is, therefore, necessary to heat in the former instance sixty-six percent more air than in the latter instance. In the case under consideration all of the air admitted to the furnace was heated from the boiler room temperature of 85 degrees to the temperature in the stack of 504 degrees, or through a range of 419 degrees. With ten to twelve percent of CO_2 there would be only one-third as much air to heat, and the saving incurred with this, over that of the actual condition, can readily be seen to be equal to the heat imparted to the sixty-six percent of air in raising it through the 419 degrees. This is a very marked saving and can be safely placed at ten percent.

The small percentage of CO_2 obtained, was doubtless due to the little attention paid to the regulation of the draft. The boiler was fired with the ash pit openings wide

open during the entire day. It is doubtful if the fireman knew that the method which he employed in firing was detrimental to the economical operation of the boiler. The main object seemed to be to maintain the required pressure regardless of how it was accomplished.

The Orsat apparatus which is used for analysing flue-gases is no longer merely an instrument for the laboratory but is being placed in many boiler rooms ofenterprising establishments throughout the country as being necessary to the complete equipment of those rooms. By allowing the fireman to use this apparatus at stated intervals, and to keep a tabulated record of the results, it not only adds interest to his work but furnishes him with information with regard to the efficiency of his method of firing. He also feels a responsibility which he would otherwise have no occasion for feeling. The actual saving in the coal bills, where the apparatus is being used, is very great.

The theoretical saving due to the feed-water heater in the system has been computed and it will be given here.

Total number of lbs. water used during trial 44,495

Temperature of feed-water entering heater - 69.2° F.

Temperature of feed-water leaving heater - 165.8° F.

One pound of water at 165.8° F. contains 134.2 B.T.U.

One pound of water at 69.2° F. contains - 37.3 B.T.U.

Heat received by each pound of water from heater - - - - 96.9 B.T.U.

Heat per pound of steam above feed-water temperature is 1159. The ratio of 96.9 to 1159 gives 8.4 percent, which represents, in percent, the saving due to presence of feed-water heater in system.

Conditions.

The important piping that serves the boilers is located in a dark space underneath the engine room, where much time is wasted, because of the inconvenience encountered, when repairs or alterations have to be made. The two plunger pumps, which are being run daily, are old and very much worn, and run at a low efficiency.

In the boiler room the arrangement is not conducive to the best results. Instead of the coal room being in line with and between the points of unloading and firing, it is placed further along in the building and necessitates carrying the coal in wheel-barrows for a distance of about seventy-five feet, in a round-about manner through the basement of the building, to the boilers. At present the coal must be carried back from the chute as it is unloaded from the car, thus making two extra handlings of the coal unavoidable.

The boilers are backed up against the outer wall with their doors opening away from the street. Such an arrangement makes it difficult for the fir eman to dispose of his ashes for he is now obliged to carry them through the engine room before dumping them. Aside from the inconvenience of carrying the ashes through the engine room, a more serious objection is raised because of the particles which are car-

ried to the bearings of the engine and which cut their surfaces.

A boiler trial was made upon but one of the United States boilers. The trial was similar to the one made upon the Scotch marine boiler, but the results have not been worked out as completely. On the day of the trial the hot feed water was all being used by the Scotch marine boiler, and, consequently, cold feed water was used for the United States boiler trial. It was not convenient to use a calorimeter on this boiler; therefore, since the quality of this steam does not enter the problem under consideration, it was not determined. The data and results for this test are as follows:

Dimensions of the United States boilers:

Length in feet - - - - - - - - - - - - - - 14
Outside diameter in feet - - - - - - - - 5.33

Thickness:

Sheets in inches - - - - - - - - - - - - - 0.875
Tube sheets in inches - - - - - - - - - - - 0.50

Combustion chamber:

Depth in feet - - - - - - - - - - - - - - - - 3.
Width in feet - - - - - - - - - - - - - - - - 4.5

Furnaces:

Length of grate in feet - - - - - - - - - - 4.5
Width in feet - - - - - - - - - - - - - - - - 4.50
Number in each - - - - - - - - - - - - - - 1

Tubes:

Outside diameter in feet - - - - - - - - - - 0.33
Length between sheets in feet - - - - - -14.
Number - 40
Spaced vertically in inches - - - - - - - 0.98
Spaced horizontally in feet - - - - - - - 0.98

Smoke pipe:

Width in feet - - - - - - - - - - - - - - - - 1.75
Length in feet - - - - - - - - - - - - - - - 1.75
Area in square feet - - - - - - - - - - - - 3.6
Height in feet - - - - - - - - - - - - - - - 85.

Ash Pit:

Height in feet - - - - - - - - - - - - - - - 2.5
Width in feet - - - - - - - - - - - - - - - - 4.5
Length in feet - - - - - - - - - - - - - - - 4.5

Heating Surface:

Tube Area in square feet - - - - - - - 149.
Combustion chamber area in square feet246.32
Furnace area in square feet - -

Dome:

Dome diameter in feet - - - - - - - - - - - 2.5
Height in feet - - - - - - - - - - - - - - 2.5

Pipes:

Live steam in inches - - - - - - - - - - -3.5
Feed-water in inches - - - - - - - - - - 2.

Coal Log. United States Boiler Trial.

Gross	Tare	Net
264.5	130	134.5
268.5	"	138.5
337.5	"	207.5
316.	"	186.
368.5	"	238.5
380.	"	250.
346.	"	216.
366.	"	236.
288.	"	158.
331.	"	201.
435.	"	305.
425.	"	295.
400.	"	270.
389.	"	259.
337.	"	207.
5252	1950	3302 Total net coal

Water Log. United States Boiler Trial.

Tank No. 1.			Tank No. 2.		
Gross	Tare	Net	Gross	Tare	Net
1214	212.5	1001.5	1238	130	1108
1335	164.	1171.	1245	289	956
1105	165.	940	1227	245	982
1193	168.	1025	1222	300	922
1308	164.	1144	1322	196	1126
1261	162.	1099	1330	275	1054
			1205	195	1010
		6380.5	1294	328	966
			1222	291	931
			1281	294	987
			1289	194	1095
			1322	328	994
					12031
					6380

Total net weight.........18411

Flue-Gas Analysis, United States Boiler Trial.

	CO_2	CO	O	Total
	3.8%	.2%	13.8%	17.8%
	2.0%	.1%	14.0%	17.0%
Average	2.9%	.15%	13.9%	17.4%

Data and Results of United States Boiler Trial.

Date, January 6, 1903.

Duration of test - - - - ten hours.

Atmospheric pressure in lbs. per sq. in. - - - - -14.3

Average gauge pressure in lbs. per sq. in. - - - -24.

Average steam temperature in degrees F. - - - - -264.49

Average temperature of feedwater in degrees F. - 70.49

Kind of coal used - Spring Valley.

Percent of moisture in coal - - - - - - - - - - - -5.8

Grate surface in square feet - - - - - - - - - - - 20.25

Water heating surface in square feet - - -

Ratio of water heating to grate surface - - -

Pounds of coal fired - - - - - - - - - - - - - - -3302

Average coal burned per hour in pounds - - - - - 330.2

Total refuse from coal, in pounds - - - - - - - -105.

Total combustile in pounds - - - - - - - - - - - - 3197

Average combustile for one hour in pounds - - - 319.70

Total water pumped into the boiler and apparently evaporated in pounds - - - - 18411

Water apparently evaporated per pound of coal burned in pounds - - - - - - - - - - - - 5.5

Average flue-gas temperature in degrees F. - - - 500

Average flue-gas draft in inches of water - - - - - .47

It can be seen from the table of results that the boiler was doing very inefficient work. 16.3 pounds of coal were burned per square foot of grate surface, while only 5.9 pounds of water were evaporated per pound of dry coal. The enormous fuel consumption is tracable to the strong draft of .47 inches of water and also to the poor grade of coal used.

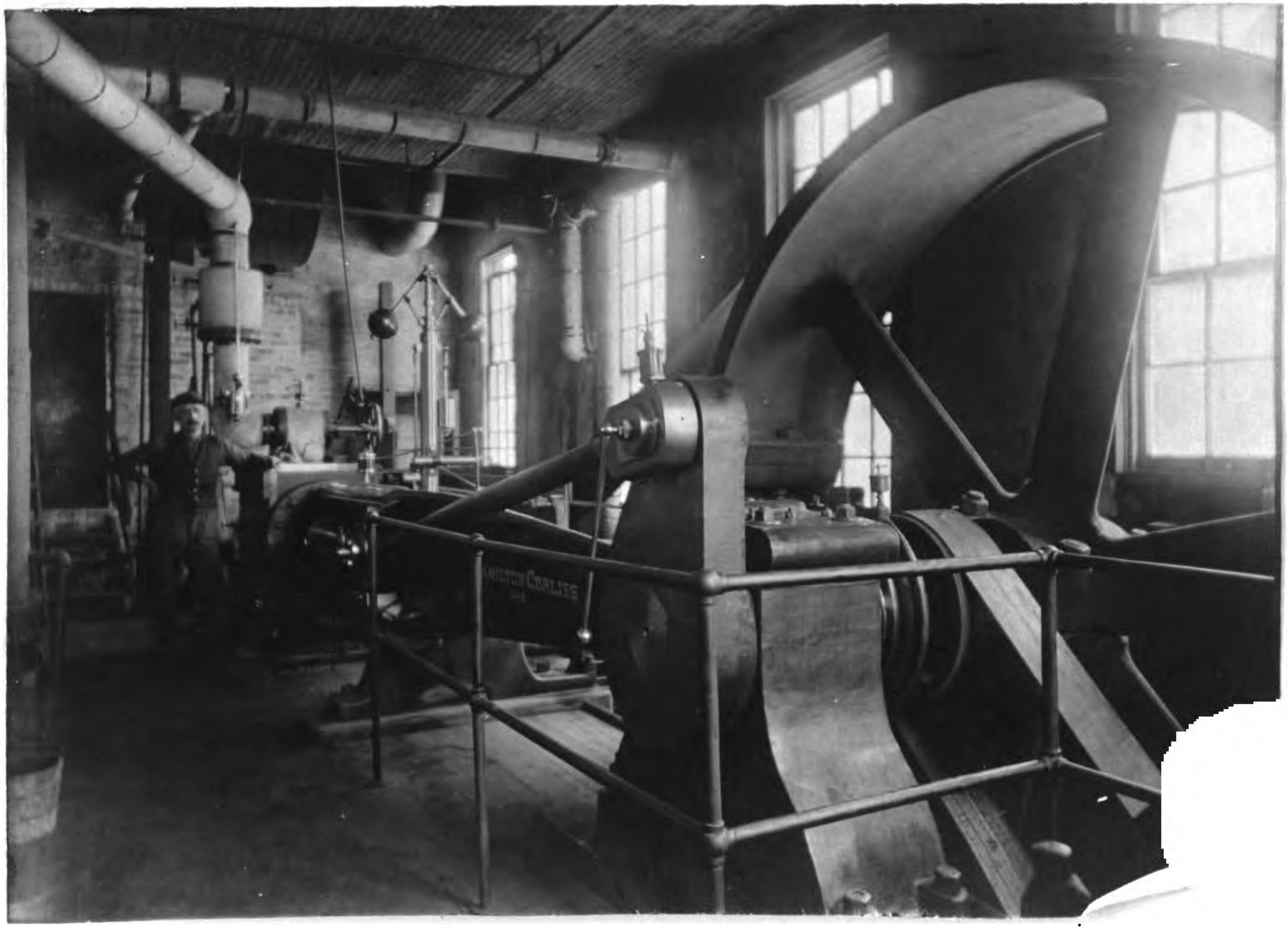
Assuming 98 percent as the quality of the steam during this trial, the boiler would have an efficiency of 66 percent, while the boiler and grate combined, would have an efficiency of 65 percent.

The flue-gas analysis shows a smaller percentage of CO_2 to have been present in the gases of this stack than in that of the Scotch marine boiler.

The conditions existing, and discussed in connection with the Scotch marine boiler trial, are for the most part the same as were encountered when the trial was made upon the United States boiler and will, therefore, not be mentioned again.

The results obtained for the United States boiler trial are low and can be attributed to the same causes which influenced the results of the Scotch marine boiler and which have already been discussed in connection with the trial on

the latter. As the test made upon the United States boiler was incidental to the purpose of this thesis, nothing more than the results were here inserted.



Engine Room.

Engine Test.

The Janesville Machine Company, finding that the old 150 H.P. engine, which had done service in driving the shafting, insufficient to provide power for their rapidly growing plant, installed a new 300 H.P. engine in the engine room on the corner of Center and River streets.

The engine is placed on a level with the street, the old foundation, with a few alterations, having been utilized as a bed for the new engine. The pumps, feed water heater, pipe connections, etc., are the same as they were before the installation.

The engine is a 300 H.P. Hamilton Corliss built on nearly identically the same principles as the Allis Corliss engine. The engine has one peculiar feature in that it is left-handed and runs backward. It was built by Hoovens, Owens and Renchler, Builders, of Hamilton, Ohio, who have established a reputation for the design of efficient Corliss engines.

The piston has a stroke of 48 inches while the cylinder has a diameter of 20 inches. The piston rod is three inches in diameter. The engine is provided with a fly wheel 12 feet in diameter, revolving on a 10 inch crank shaft. The valve motion is regulated by an eccentric having a throw of 20 inches. The pipe which supplies the engine with live

steam is 6 inches in diameter, while the exhaust pipe is 7 inches in diameter, the live steam pipe being connected to a 350 H.P. Scotch marine boiler in the adjacent boiler room, while the exhaust steam finds an outlet through a feed water heater and thence through the steam coils in the shops on the south side of Center street in winter, while in summer the steam, after passing through the heater, is exhausted into the open air.

In making a test of this engine it was the object of the authors of this thesis to determine, as far as possible, what the engine was doing in an average day's run, when the shops were running under ordinary working conditions. It was also their object to determine, by actual test, how much power was consumed in overcoming friction in all the line shafting throughout the plant and thereby determining the efficiency of the plant; and also to determine the power lost, due to friction in the shafting of the separate departments.

Accordingly, on January 7, 1903, the engine was started as usual at 7: a.m. and operations commenced under ordinary working conditions. Cards were taken with the indicators every ten minutes throughout the ten hour test. Readings of the calorimeter and boiler pressure were taken every half hour, while a speed counter, attached to a reciprocating part, recorded the revolutions. In this manner

readings were taken of the different instruments throughout the run and data were obtained, from which the power consumption during an average day's run could be calculated. The horse-powers for both head and crank end were computed and arranged in a table. From this table on page 49, one can readily compare the horse-power developed in head and crank end and from a curve, on page 53, one can note the variation of horse-power developed by the engine during the test.

On January 9th, 1903, after regular working hours, when the belts throughout the plant were running on idle pulleys, indicator cards were taken from the engine and the power necessary to overcome friction was determined. Then one after another, the various departments were "cut out" and cards were taken as before of the various conditions and the power determined. By subtraction, the power necessary to overcome the friction in the separate departments was determined. In some cases, it was not practicable to remove a belt driving a department. In such an event, the only thing remaining to do was to get the power consumption for several departments. While testing the separate machines in the plant, it was convenient in many cases to determine the power necessary to drive the line shaft or counter shaft of a department. The power necessary to drive these with a few exceptions, can be found in Tables on page 52,

for the department in question. Those departments which it was necessary to bunch because of conditions mentioned above, can be separated by the method explained and the power determined. In the case of the last two named departments, page 52, it became necessary to include the engine friction, since it was not practicable to remove the large driving belt from the fly wheel. It had been the intention of the authors, when looking over the ground, to determine the mechanical efficiency of the engine but the local conditions prevented them from carrying out their intentions in full.

In tabulating the data, relative to the friction tests of shafting and belts in different departments of the plant, it became necessary because of the limited space allowed to use numerals to represent the different conditions. Accordingly, they have been arranged as follows:

I. Represents the conditions of an average ten-hour run when the machines are running at a normal rate.

II. Represents the condition, in which the shafting and belting is running idle in all the departments. These departments include the foundry, machine shop, blacksmith shop, plow shop, wood shop, and warehouse machine shop.

III. Represents the condition in which the shafting and belting is running idle in the machine shop, blacksmith shop, plow shop, wood shop, and warehouse machine shop, with

foundry"cut out."

IV. Represents the condition in which the shafting and belting is running idle in blacksmith shop, plow shop, wood shop, and warehouse machine shop with foundry and machine shop "cut out."

V. Represents the condition in which the shafting and belting is running idle in wood shop, warehouse machine shop with the foundry, machine shop, blacksmith shop and plow shop "cut out."

Now, it is evident that, by subtracting the various values of horse-power which have been tabulated in the table on page 52, according to the numerals explained, the power necessary to do useful work in the whole plant and the power necessary to overcome friction in the various departments can be determined. Useful work being understood as meaning the power required above that used when the shafting is running empty.

On page 124, is a drawing which will give some idea of the plan of the Janesville Machine Company and the position of the "line shafts" and "counter shafts" with the departments which they drive.

Diagrams of cards taken during different stages of the test and illustrating variation in cut off, compression, etc., may be found on pages 56 - 60.

The instruments used in this part of the test consisted of:

One throttling calorimeter with U tube,

One steam gauge,

One speed counter,

One reducing motion,

One set of Tabor indicators No. 5479-5480, indicator springs sixty pounds.

The instruments were tested and calibrated in the steam laboratories of the University of Wisconsin by comparison with proper standards.

Data and curves for these calibrations can be found on page 146.

Engine Test.

Dimensions:

1. Kind of engine - - - - Hamilton Corliss.
2. Name of makers - - -Hoovens, Owens & Rentschler Co.
3. Diameter of cylinder, inches - - - - - - - - - - -20
4. Length of stroke, inches - - - - - - - - - - - - 48
5. Diameter of piston rod, inches - - - - - - - - - 3
6. Scale of indicator springs, pounds - - - - - 60
7. Piston area, square inches - - - - - - - - - - -314.16
8. Eccentricity, inches - - - - - - - - - - - - - -20
9. Area of live steam pipe, square inches - - - 6
10. Area of exhaust steam pipe, square inches - - 7
11. Diameter of fly wheel, feet - - - - - - - - - - 12

Speed of Engine.

Beginning	Ending	Rev. per hour
10:17 - 812708	11:47 - 819103	4263
1:10 - 820400	2:10 - 824780	4380
2:10 - 824780	3:10 - 829153	4373
3:10 - 829153	4:10 - 835606	4302

4329 = average revolutions per hour, or

72.1 = average revolutions per minute.

ENGINE TEST LOAD.

No.	Time	M.E.P. H.E.	M.E.P. C.E.	I.H.P. H.E.	I.H.P. C.E.	Total I.H.P.
			Condition I.			
1	7:00	21.00	18.45	57.80	49.48	107.28
2	7:10	20.70	20.55	57.00	55.00	112.00
3	7:20	23.95	24.75	71.40	66.40	137.80
4	7:30	21.60	23.25	59.48	62.50	121.98
5	7:40	25.35	24.90	69.75	66.75	136.50
6	7:50	25.50	23.25	70.20	62.50	132.70
7	8:00	22.50	20.55	61.90	55.00	116.90
8	8:10	24.75	23.70	68.00	63.50	131.50
9	8:20	24.90	20.45	68.60	54.70	123.30
10	8:30	22.50	19.50	61.90	52.22	114.12
11	8:40	21.45	20.25	59.00	54.20	113.20
12	8:50	21.90	19.05	60.20	51.00	111.20
13	9:00	19.95	20.25	54.98	54.40	109.38
14	9:10	22.50	21.75	61.80	56.70	118.50
15	9:20	24.30	22.05	66.85	59.02	125.87
16	9:30	23.40	21.70	64.30	58.10	122.40
17	9:40	21.45	20.40	59.00	54.70	113.70
18	9:50	22.50	21.60	61.90	57.80	119.72
19	10:00	21.25	20.25	58.70	54.42	113.12
20	10:10	22.95	21.00	63.10	56.22	119.32
21	10:20	23.40	19.65	64.47	52.60	117.07
22	10:30	22.95	19.80	63.17	53.00	116.17
23	10:40	21.75	19.20	59.80	51.41	111.21
24	10:50	22.20	21.15	61.10	57.10	118.20
25	11:00	21.45	20.70	59.10	55.46	114.56
26	11:10	24.00	22.05	66.00	59.25	125.25
27	11:20	22.80	20.25	62.78	54.40	117.18
28	11:30	22.05	18.60	60.60	49.76	110.36
29	11:40	20.10	19.80	55.38	53.00	108.38
30	11:50	19.80	19.05	54.49	51.00	105.49
31	12:00	19.05	16.80	52.50	45.00	97.50
32	1:00	15.60	16.20	42.90	43.40	86.30
33	1:10	23.40	22.35	64.40	59.87	124.27
34	1:20	23.55	21.60	64.75	78.80	122.55
35	1:30	22.50	23.55	61.80	63.00	124.80
36	1:40	23.55	20.55	64.80	55.00	119.80
37	1:50	21.00	21.45	57.70	57.47	115.17
38	2:00	20.55	21.00	56.50	56.20	112.70
39	2:10	23.70	21.30	65.23	57.00	122.23

Engine Test Load.- Continued.

No.	Time	M.E.P. H.E.	I.H.P. H.E.	M.E.P. C.E.	I.H.P. C.E.	Total I.H.P.
			Condition I.			
40	2:20	22.95	63.10	22.95	61.46	124.56
41	2:30	21.30	58.63	21.75	58.20	116.83
42	2:40	22.95	63.15	20.40	54.63	117.78
43	2:50	22.65	62.40	20.70	55.49	117.89
44	3:00	20.70	57.00	18.60	49.78	106.78
45	3:10	19.35	53.25	20.10	53.90	107.15
46	3:20	22.35	61.50	22.35	59.77	121.27
47	3:30	21.60	59.50	21.75	58.23	117.73
48	3:40	23.40	64.50	22.20	59.50	124.00
49	3:50	23.55	64.75	21.30	57.15	121.90
50	4:00	24.45	67.20	21.22	57.00	124.20
51	4:10					
52	4:20	24.00	66.00	23.10	62.00	128.00
53	4:30	22.80	62.70	22.20	59.50	122.20
54	4:40	22.80	62.70	21.00	56.20	118.90
55	4:50	23.10	63.25	21.00	56.30	119.80
56	5:00	23.85	65.57	20.40	54.65	120.22
57	5:10	23.10	63.50	21.15	56.45	119.95
58	5:20	20.25	55.60	18.45	49.47	105.07
59	5:30	20.25	55.80	18.75	50.22	106.02
60	5:40	21.45	59.00	20.10	53.80	112.80
61	5:50	13.35	36.75	15.45	41.42	78.17
62	6:00	11.80	32.45	13.95	37.40	69.85

Engine Test Friction.

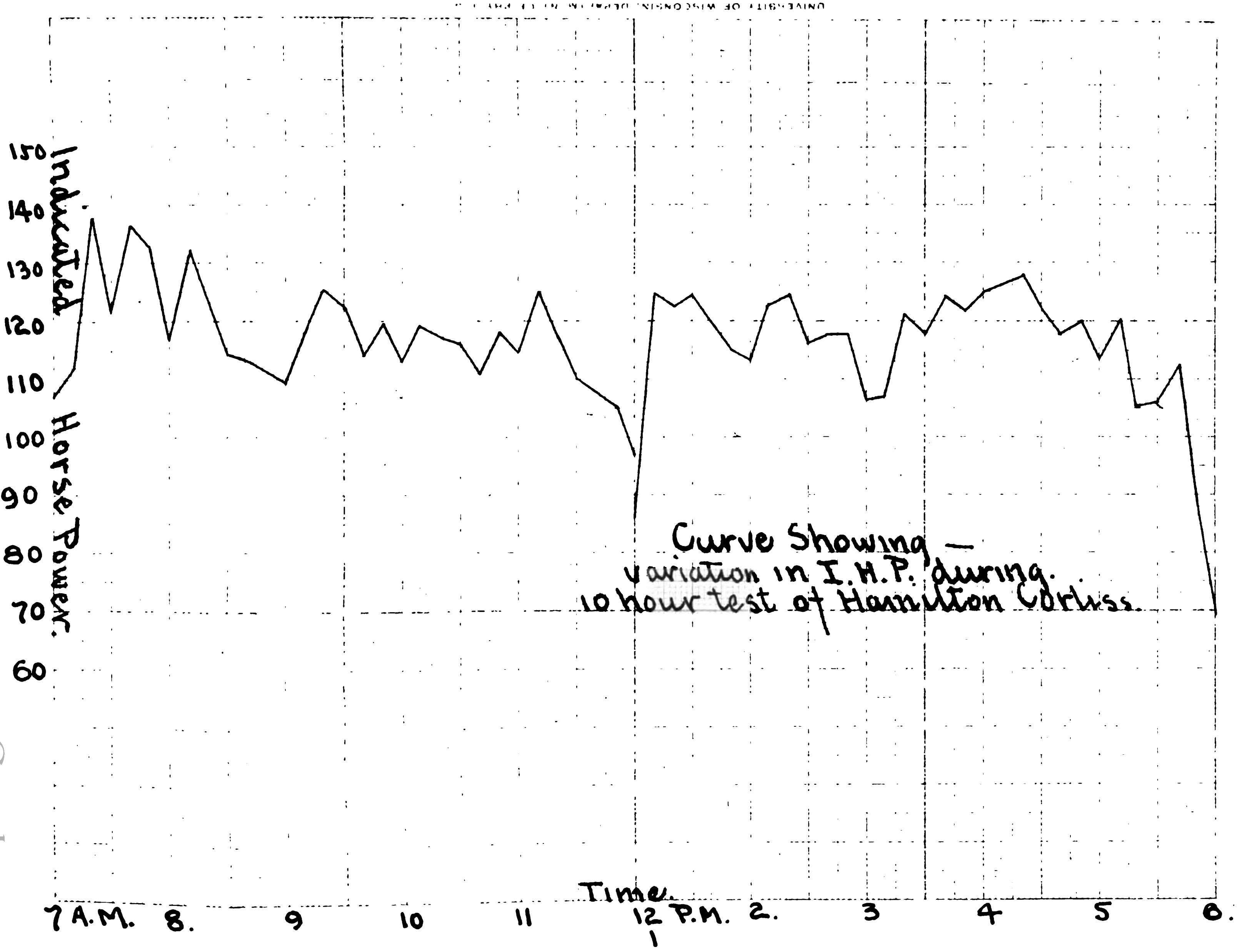
No.	Time	M.E.P. H.E.	M.E.P. C.E.	I.H.P. H.E.	I.H.P. C.E.	Total I.H.P.
			Condition II.			
1	6:01	13.80	15.00	38.00	40.20	78.20
2		13.50	14.25	37.10	38.20	75.30
3	6:04	13.35	13.35	36.70	35.80	72.50
4		12.90	12.90	35.60	34.60	70.20
			Condition III.			
5	6:05	11.55	11.40	31.75	30.55	62.30
6		10.54	10.65	28.95	28.55	57.50
7	6:08	10.80	11.55	29.70	31.00	60.70
			Condition IV.			
8	6:09	10.95	11.70	30.10	31.35	61.45
9		10.80	10.05	29.70	26.95	56.60
10		11.10	10.35	30.05	27.75	57.80
			Condition V.			
11	6:13	8.90	7.50	24.43	20.10	44.53
12		9.60	7.50	26.40	20.10	44.50

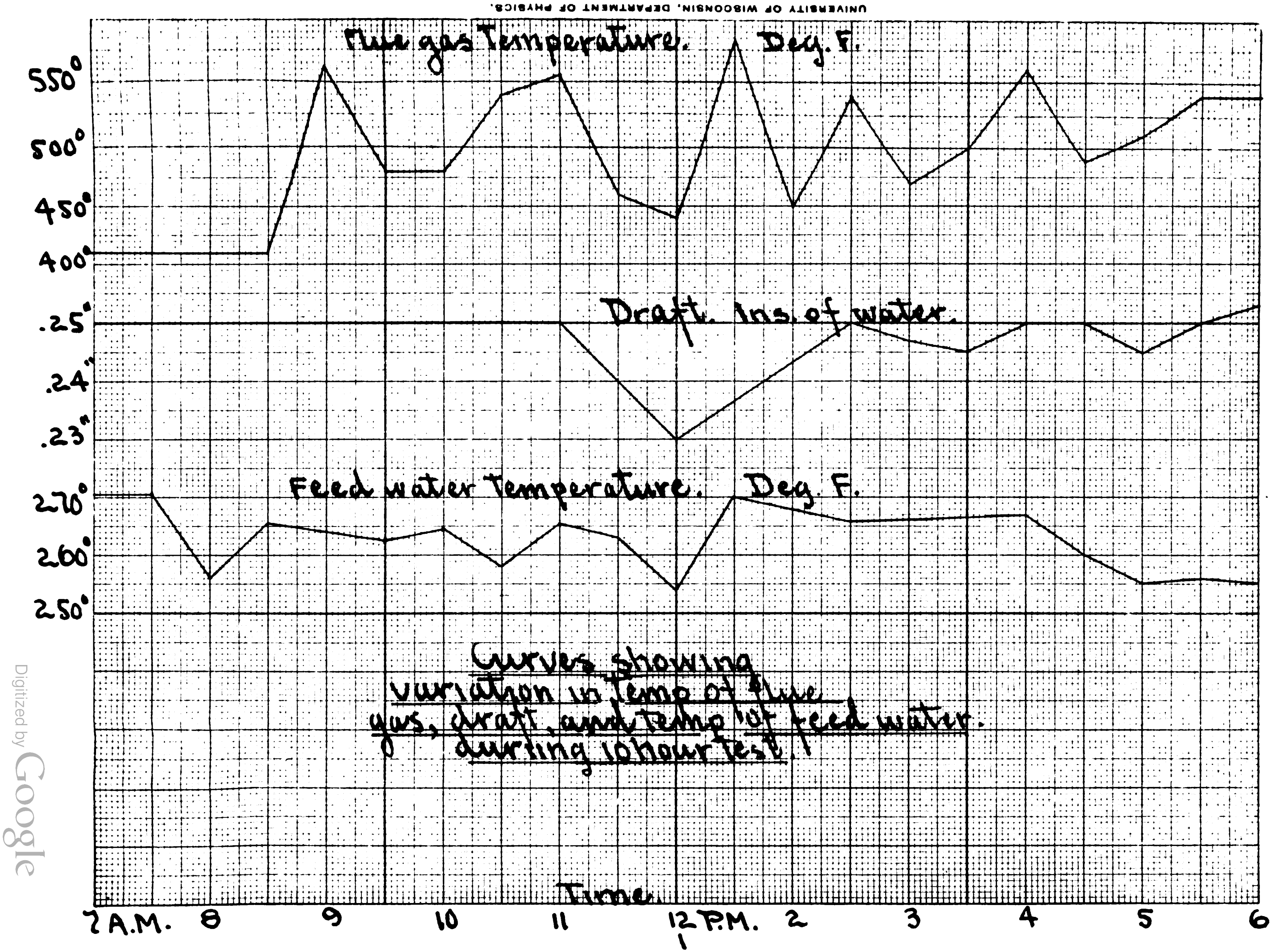
Report of Test.

1. Duration of test, hours - - - - - - - - - - - - - - - - -10
2. Revolutions per minute - - - - - - - - - - - - - - - - - - 72.1
3. Gauge reading, boiler, lbs. per sq. in. - - - - - - 79.7
4. Barometer, lbs. per sq. in. - - - - - - - - - - - - - - -14.2
5. Feed water temperature, degrees Fahrenheit - - - -165.8
6. Quality of steam, percent - - - - - - - - - - - - - - - -98.93

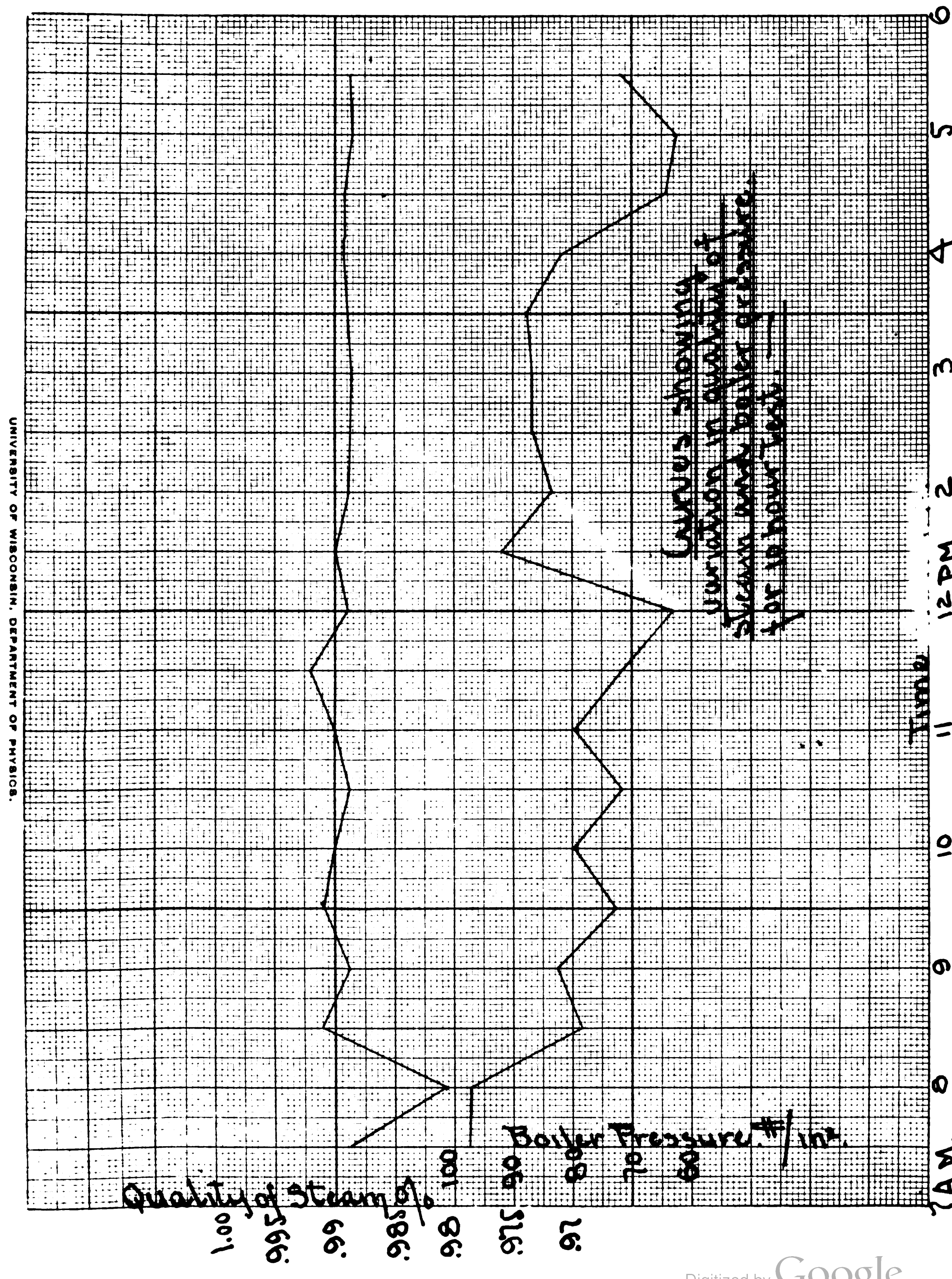
	H.E.	C. E.
7. Piston displacement, cubic feet - - - - - -	2.18	1.98
8. Engine constant - - - - - - - - - - - - - - - - - -	2.75	2.68
9. Cut off, percent stroke - - - - - - - - - - -	-21.	17.
10. Release, percent stroke - - - - - - - - - -	100.	100.
11. Compression, percent stroke - - - - - - -	94.1	94.1
12. Pressure at cut-off, pounds - - - - - - -	66.8	72.0
13. Pressure at release, pounds - - - - - - - -	7.5	7.5

14. Average mean effective pressure, lbs. per sq. in.
    Condition I - - - - - - - - - - - - - - - - 21.28
    Condition II - - - - - - - - - - - - - - - 14.48
    Condition III - - - - - - - - - - - - - - - 11.10
    Condition IV - - - - - - - - - - - - - - - -10.95
    Condition V - - - - - - - - - - - - - - - - 8.86
15. Average indicated horse-power,
    Condition I -115.56
    Condition II - 74.10
    Condition III -60.15
    Condition IV - 58.63
    Condition V -45.51
16. (I) = Average indicated horse power of engine - - 115.56
17. (II) = Indicated horse power absorbed by total shafting - - - - 74.55
18. (I - II) = Indicator horse power required to do useful work - - - - - - 41.01
19. Ratio of useful work to frictional power lost - - - .543
20. Percent loss from friction in total shafting - - - 64
21. (II - III) = Indicated horse power required to overcome friction in foundry - - - - 13.89
22. (III - IV) = Indicated horse power required to overcome friction in machine shop 1.53
23. (IV - V) = Indicated horse power required to overcome friction in blacksmith shop and plow shop 13.12
24. (V) = Indicated horse power required to overcome friction in main shaft, warehouse machine shop, wood shop and engine - - - - - - - - -45.51
25. Weight of steam per minute, pounds - - - - - - - - - 74.16
26. Weight of steam per revolution, pounds, - - - - - - - .10
27. Weight of steam per I.H.P. hour, pounds - - - - - -38.5
28. Weight of dry steam per I.H.P. hour, pounds - - - 38.08

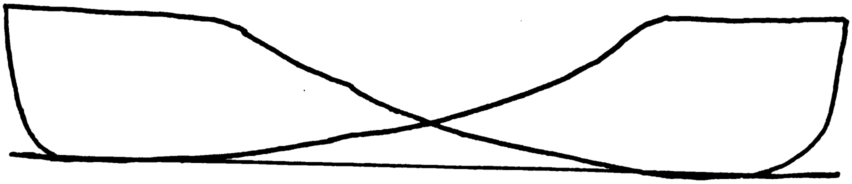

Curve Showing —
variation in I.H.P. during.
10 hour test of Hamilton Corliss.
Indicated Horse Power.
150
140
130
120
110
100
90
80
70
60
Time.
7 A.M.
8.
9
10
11
12 P.M.
1
2.
3
4
5
6.



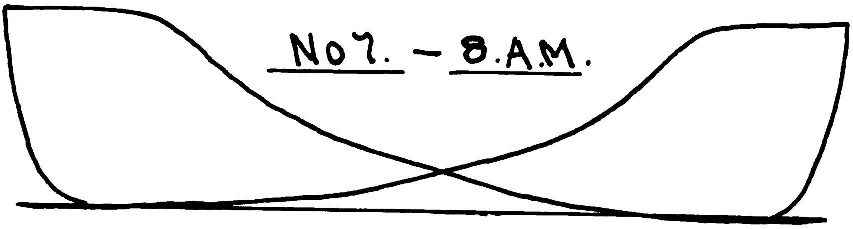
Curves showing variation in temp of flue gas, draft, and temp of feed water during 10 hour test.


Curves showing variation in quality of steam and boiler pressure for 10 hour test.
Time
7 A.M.
8
9
10
11
12 P.M.
2
3
4
5
6
Quality of Steam %
1.00
.995
.99
.985
.98
.975
.97
Boiler Pressure #/in².
100
90
80
70
60
UNIVERSITY OF WISCONSIN. DEPARTMENT OF PHYSICS.

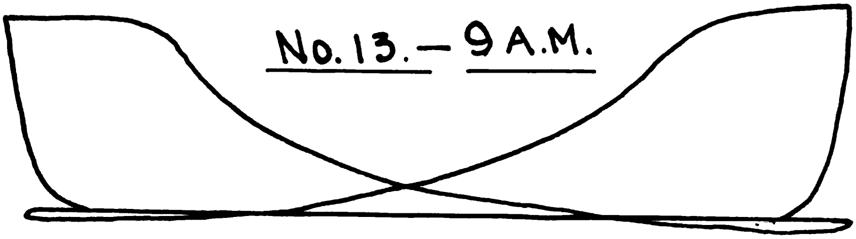
No 1 – 7. A.M.



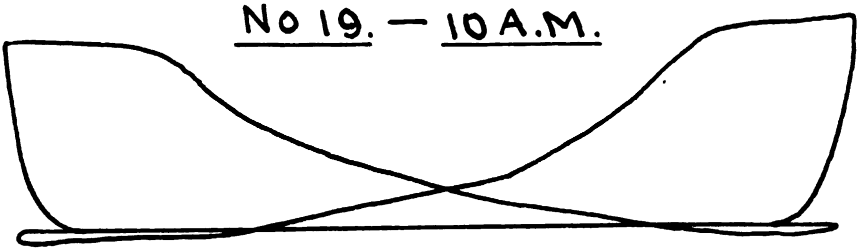
No 7. – 8. A.M.



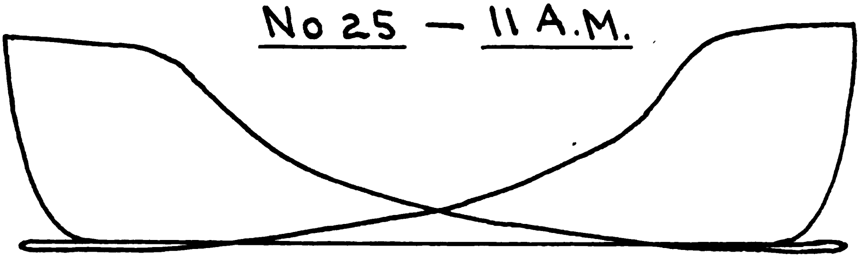
No. 13. – 9 A.M.



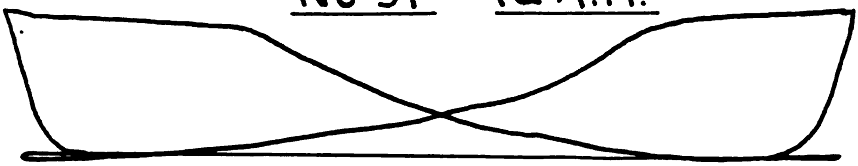
No 19. — 10 A.M.



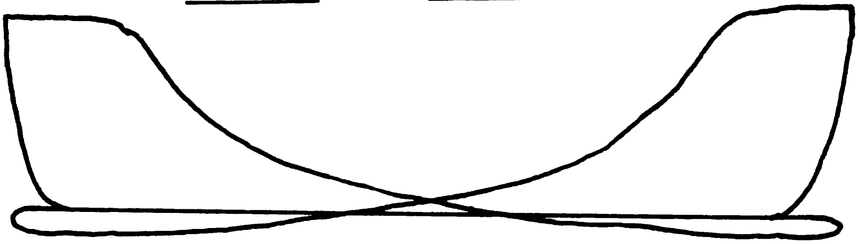
No 25 — 11 A.M.



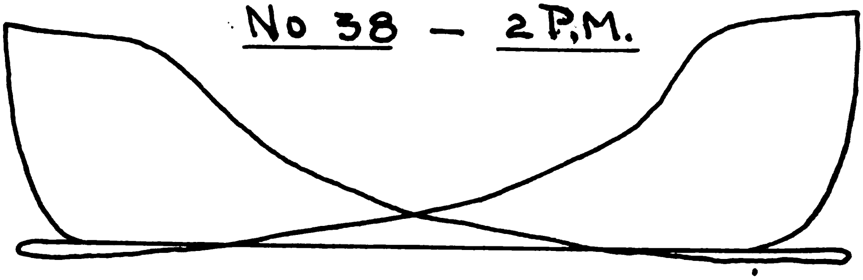
No 31 — 12 A.M.



No 32 — 1 P.M.



No 38 — 2 P.M.



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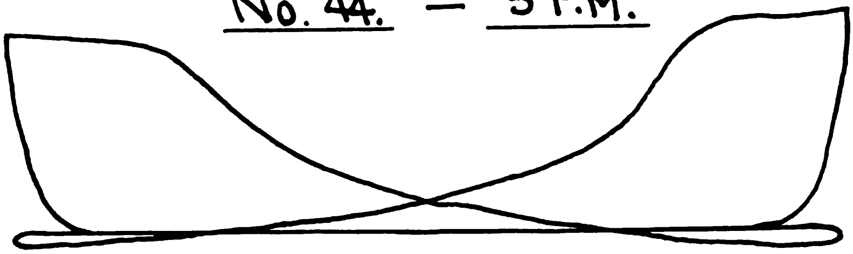

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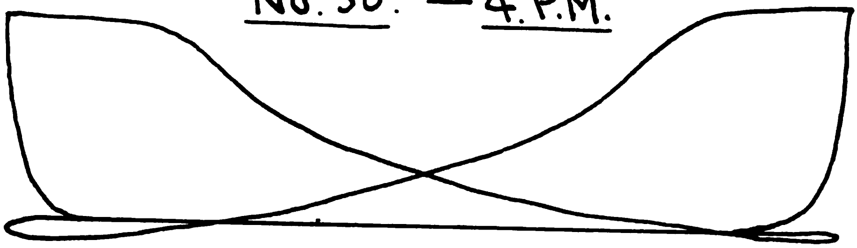

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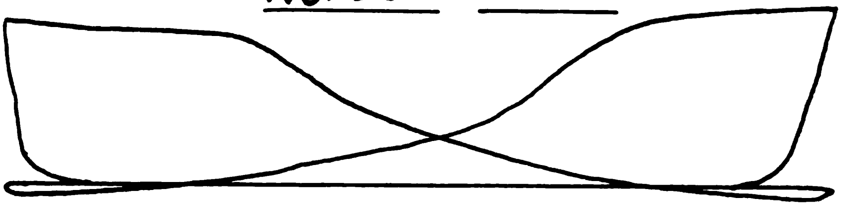
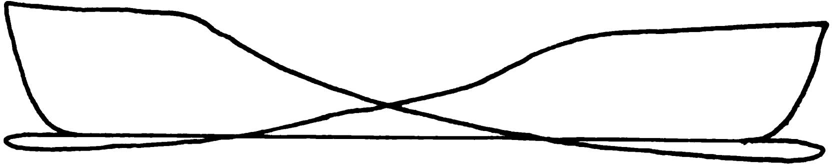
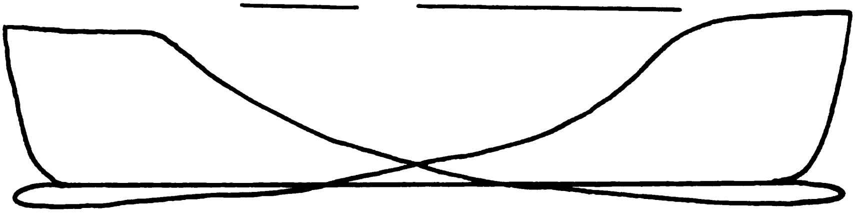


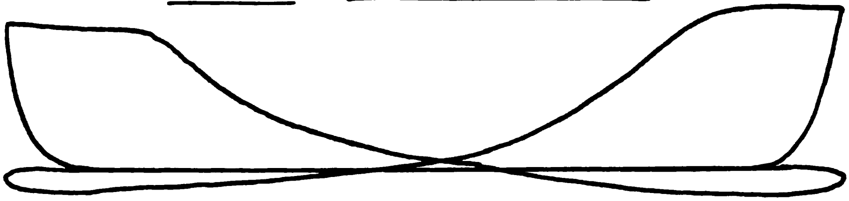
No 62 - 6 P.M.



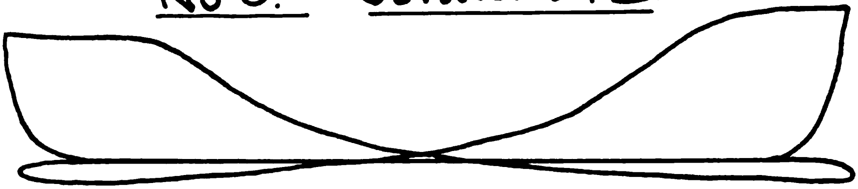
No I. - Condition II.



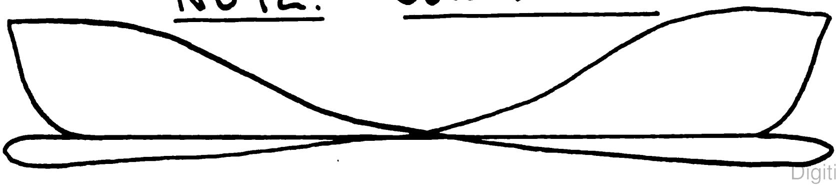
No 5. - Condition III.



No 8. - Condition IV.



No 12. - Condition V.



Conclusion to Engine Test.

Under the best of conditions, the losses in line shafting, counter shafting, etc., in transmitting power from one part of a plant to another, due to the friction in belts, bearings, etc., are always large, and under the most favorable circumstances seldom equals less than one-half the total power developed. Although the conditions in the Janesville Machine Company's shops are no worse than the conditions in the average plant, nevertheless the losses due to friction in line shafting, etc., are quite large.

As may be seen from the data on the previous pages, the loss in power due to friction is 64 percent, while the useful work consumes only 36 percent and it is seen that only 54 percent as much power goes to do useful work as goes to overcome friction in the different parts of the plant. Under the existing conditions it is difficult to suggest a remedy for this evil since, owing to the manner in which the plant is laid out, long line shafts and great lengths of belts are, in most cases, necessary. Like most rapidly growing plants, the buildings for the various departments have been erected without due regard to the position of the power plant, and consequently there is now the necessity of extending shafting long distances, while, if the power

plant had been more centrally located, under the present system, some of the shafting might have been done away with.

Undoubtedly the greatest source of loss is due to the main line shaft which runs from the power plant and Center and River street over to the warehouse machine shop, a distance of 235 feet. Besides this, there is an enormous loss in the shafting in the various departments.

Another source of loss is from the friction in the belting throughout the shops and the bevel gear, which furnishes power to the machine shop. A possible suggestion might be made in this case. Although the distance is comparatively short between the main shaft and the machine shop a quarter-turn belt or a rope drive might be advantageously used, since the efficiency of either is higher than that of a bevel gear and it is especially high with the rope drive where properly constructed.

Tests of Separate Machines.

The intentions of the authors of this thesis were not only to investigate the losses in power transmission, as the subject might suggest, but also to make an estimate of the cost of installation and maintenance of an electric transmission plant, so that a comparison of the two systems might be made. This would have been comparatively easy and could have been done by taking indicator cards from the engine if the load had been a steady one like a flour mill. But the load was constantly changing as the table on page , shows. In some cases, a motor would be installed which would run a whole department while in others it might be advisable to operate single machines with separate motors. The reason for this is that the efficiency of a motor is highest when the motor is running at full load, and, if a single motor were installed in a department where some of the heaviest machines are only run at certain intervals, the motor would run at a low efficiency when these heavy machines were not in operation and a loss would be necessarily incurred.

To determine the size and number of motors needed, that is, to determine the horse-power required to run the machines and departments, a motor was belted to the machines or shafts, and the power consumption determined.

Lack of time prevented the testing of each and every machine. So, in the event of several machines of the same size and design, one only would be tested and the others were assumed to take the same amount of power. In some cases, it was impossible to make a run of sufficient duration to heat the machine and motor up to their normal running temperature, but where this was possible, this was done. In most cases, where the power was determined when the machine was working, the work was being done at the normal rate, though in some cases, as in saws, planers, etc., the heaviest work was put into the machine.

In several cases, the motor was belted to the line shaft, readings were taken of line shafts alone and then with a single machine, both working and empty. This was necessary, for two reasons, first, because of lack of time, second, because some of the tests had to be made out of shop hours so as not to delay the work of the men. Of course the friction of shafts varies somewhat with the load but this variation is quite small and, for our purpose, negligable.

In the case of large machines, the motor was belted direct, but in some instances, as in the test of emery wheels, riveters, etc., the counter-shaft was considered as a part of the machine and the "Power consumed by Machine" includes that consumed by the countershaft also. From the "Index Reference" can be found just what is included under the head

"Power consumed by Machine."

The motor used was a 15 H.P. Northern Electric of 750 revolutions per minute, requiring a direct current of 220 volts. This current was kindly furnished by the Janesville Electric Company. The motor was placed on a four-wheeled skid so that it could be easily moved from place to place.

The different speeds were obtained by two motor pulleys and also by varying the armature current by means of a water rheostat in the armature circuit.

The method of procedure was as follows: The speed of the machine or shaft to be tested was determined by means of a speed counter, the connection to driving shaft cut and motor belted to machine. An ammeter, water rheostat and starting box were placed in the armature circuit and an ammeter and field rheostat in the field circuit.

It should be remembered that the field resistance was placed in the field circuit not to vary the field current, thereby regulating the speed, but to keep the field current as nearly constant as possible. This made the "testing out" of the motor much simpler than it would otherwise have been. The pressure across the armature and line terminals was obtained by means of a voltmeter and double switch. The speed was then regulated to as near normal as possible and readings of motor speed, armature current, field current, armature voltage and line voltage were taken. The instruments used in

the test were the same as those used in the "testing out" of the motor. The readings recorded in the table are the averages of several taken during the test.

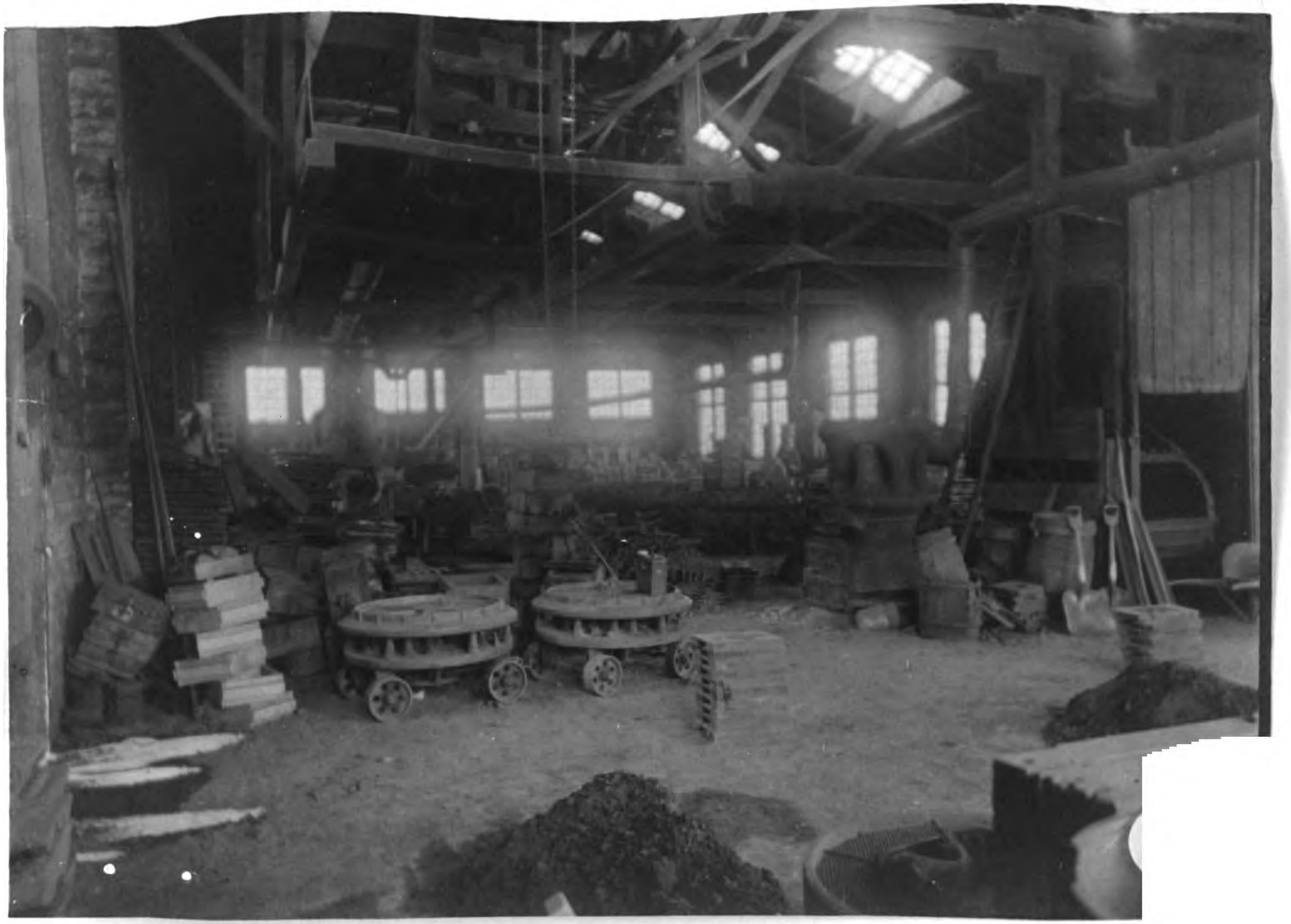
The instruments used were:

1. Weston ammeter, No. 6258, with range 0-75,
2. Weston ammeter, No. 5750 with range 0- 5,
3. Weston voltmeter, No. 4450 with range of 0-300-600.

These were tested and calibrated by comparison with the proper standards in the laboratories of the University of Wisconsin and found to be correct. Tables and curves can be found on Appendix II, page 140.

The determination of the "Power consumed by Machine" and the "Motor Losses" will be fully described in Appendix I, page 138.

It should be kept in mind that when work is in the machine the "Machine Condition" is called "Working." When the machine is running without work, it is called "Empty." And when all belts are on idle pulleys, "Idle."



Foundry, looking east.

Foundry.

Instrument Readings.

	Speed	Motor Loaded				Moto Empt
Name of machine	Motor	Arm. C	Arm. V	Field C	Line V	Arm.
(a)	655	37.00	202	.90	228	3.
(b)	665	13.75	203	.88	231	3.
Fan	---	------	---	---	---	---
(d)	671	48.00	204	.85	221	3.
(a)	655	37.00	202	.90	228	3.
One Rattler	---	------	---	---	---	---
(f)	649	45.00	208	.87	223	3.
(a)	655	37.00	202	.90	228	3.
Emery Wheel	---	------	---	---	---	---
(h)	616	42.80	199	.90	222	2.
(i)	---	------	---	---	---	---
Rope Drive	---	------	---	---	---	---

Foundry.

Watts			Horse-Power			
Total consumed	Motor loss	Delivered by motor	Delivered by motor	Consumed by mach.	Machine condi- tions	See Index Refer.
7675	727.5	6947	9.32	----	---	(a)
2998	211.8	2786	3.74	----	---	(b)
----	-----	----	----	5.58	Working	(c)
9988	1116.1	8872	11.89	----	---	(d)
7675	727.5	6947	9.32	----	---	(a)
----	-----	----	----	1.29	Working	(e)
9554	1001.8	8552	11.45	----	---	(f)
7675	727.5	6947	9.32	----	---	(a)
----	-----	----	----	2.13	Working	(g)
8720	926.0	7794	10.41	----	---	(h)
----	-----	----	4.74	----	---	(i)
----	-----	----	----	5.67	Working	(j)

Foundry.

The foundry was in a very crowded condition and it was impossible to place the motor inside the building. As the main shaft projected a few feet through the north wall, it was possible to make our connection just outside the door. This was done. The test was commenced at 3 p.m. and was continued throughout the entire heat. The foundry gets its power from a rope drive running across River street. The rope was held away from the sheave during the test.

It will be noticed that (b), the power required to run the line and counter-shafts with belts running to idle pulleys, is high. This appears unreasonable at first sight, as the shafting, etc., is not of unusual length or dimensions. But it must be remembered that the pulley to which the motor was belted, was at the end of the shaft and twenty inches away from the end bearing. The bearings were ten feet apart. The pull of the belt produced a bending moment which consumed considerable power. This loss does not remain constant but increases with the load. Therefore, all of the readings for "Power Consumption" are high.

(a) This condition consists of a line shaft 54 feet in length, to which is belted a 21 feet long counter-shaft with belts running idle to four rattlers. Also an emery wheel running empty and belts running to idle pulleys on an elevator. Also a fan or blower which provides blast for the

cupola.

(b) This is identically the same as (a) except that the fan was cut out.

(a) - (b) = Power consumed by fan or blower.

(c) The fan is what is known as a Root blower.

It was thought that the blower consumed more power as the heat progressed due to the slag filling the interstices of the cupola, and impeding the flow of air. The readings did not show this to be a fact as can be seen by the accompanying log.

Time.	Armature Current.	Armature Voltage.
3:20	48.5	204
3:30	46.0	212
3:40	49.0	207
3:50	47.5	208

The readings are for line shaft, countershaft, fan, belts running idle to elevator and emery wheel working.

It will be seen that when the armature current increases, the voltage decreases and vice versa, so that the watts consumed remains practically the same. Some of the variation was undoubtedly caused by the variation of the work done on the emery wheels.

(d) This includes the line and countershafts, Root blower, emery wheel empty, belts running idle to elevator and two rattlers working.

(d) - (a) ÷ 2 = Power consumed by one rattler working.

(e) The rattlers are four in number, three being three feet in diameter and three feet long, while the fourth is one foot in diameter and three feet, four inches long. The smaller one was not tested.

(f) This includes the line shaft, Root blower, rattler counter shaft with belts running idle and emery wheel working. The elevator belts are also running to idle pulleys.

(f) - (a) = Power required to run the emery wheel working.

(g) The emery wheel is an ordinary emery wheel for grinding castings; which is light work. It has a short counter shaft overhead, the power to run which is included in that of "Emery Wheel Working."

(h) This includes the line shaft, counter shaft, and rope drive with emery wheel running empty. Also belts running to idle pulleys on elevator.

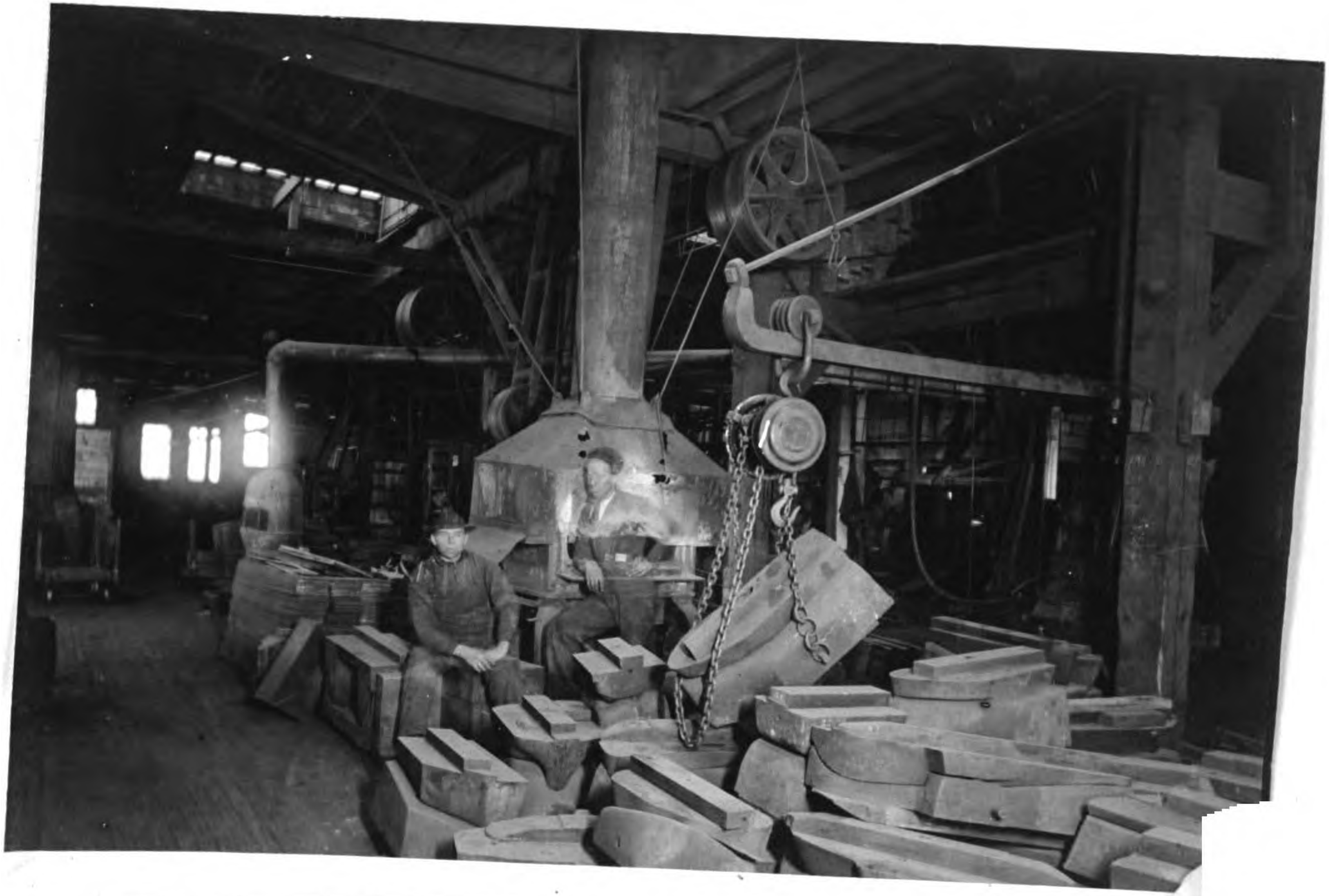
(i) This condition is the same as (h) except that the rope drive was cut out. It will be noticed that no readings are recorded for (i). This was due to an over sight on our part at the time of the test. But we know the power required to drive the line shaft and counter shaft together, (b), and, from the many emery wheels tested about the works, we can get a good average of the power required to run the emery wheel, running empty. This we did, taking one horse

power for our average, and, adding this to (b) or the power required to run the line shaft, we can subtract the sum (i) from (h) and get the power required to run the rope drive.

(h) - (i) = Average power consumed by rope drive.

(j) This consists of a double rope drive with sheaves 150 feet apart. The sheaves are of 60 inches diameter and make 240 revolutions per minute. There is a suitable arrangement at the foundry end to take up the slack of the rope. The rope is of hemp, 700 feet long, 1-1/8 inches in diameter and was calculated to transmit 40 horse-power. It travels about .7 mile per minute.

It must be remembered that the power was applied to the rope drive at the foundry end and that the lower rope was the driving rope instead of the upper, as is the case when the engine is pulling the foundry.



Blacksmith Shop, looking north.

Blacksmith Shop.

Instrument Readings.

	Speed	Motor Loaded				Moto Empt
Name of Machine	Motor	Arm.C	Arm.V	Field C	Line V	Arm.
Bull dozer	578	11.75	229	1.	238	2.9
Bull dozer	525	6.75	231	1.	238	2.9
Bull dozer & c. shaft	599	8.17	195	.96	233	2.8
Shear & c. shaft	585	11.25	199	.96	233	2.8
C. shaft alone	595	6.66	191	1.0	234	2.6
Bull dozer	---	----	---	----	---	---
Shear	---	----	---	----	---	---
Fan & c. shaft	354	47.5	118.3	.95	211	2.0
Counter shaft	358	9.00	117.5	1.0	230	2.0
Fan	---	----	-----	----	---	---
Small press & c. shaft	385	5.00	123	1.0	236	2.5
Small press & c. shaft	390	7.75	133	1.0	234	2.4
Riveter & c. shaft	586	12.5	204	1.0	231	3.0
Riveter & c. shaft	650	6.00	216	1.0	237	2.9
Punch	195	6.5	103	1.0	232	2.6
Punch	190	6.6	101	.99	232	2.7
Trip ham. & c. shaft	320	12.8	146	1.0	241	2.8
Counter shaft alone	288	6.00	239	1.0	241	2.6
Trip hammer	---	----	---	---	---	---
Trip ham. & c. shaft	295	16.8	163	1.0	246	2.6
Counter shaft	288	6.00	239	1.0	241	2.5
Trip hammer	---	----	---	---	---	---
Trip ham. & c. shaft	381	10.8	163	1.0	235	2.6
Counter shaft	288	6.00	239	1.0	241	2.6
Trip hammer	---	----	---	---	---	---
Polishing wheel & c. shaft	556	30.3	176	.90	213	3.2
Emery wheel & c. shaft	575	27.5	182	.92	217	3.1
Counter shaft alone	558	19.7	170	.93	216	3.0
Polishing wheel	---	----	---	----	---	---
Emery wheel	---	----	---	----	---	---

Blacksmith Shop.

Watts Total consumed	 Motor loss	 Delivered by motor	Horse-Power Delivered by motor	 Consumed by mach.	Machine condi- tions	See Index Refer.
2932	227.2	2704	3.62	3.62	Working	(a)
1798	187.0	1611	2.16	2.16	Empty	(a)
1816	182.9	1630	2.19	----	-----	(b_1)
2464	209.0	2255	3.01	----	-----	(b_2)
1506	186.	1320	1.77	----	-----	(b)
----	-----	----	----	.42	Working	(c)
----	-----	----	----	1.24	Working	(d)
5821	524.0	4697	6.29	----	-----	(e)
1288	200.4	1088	1.46	1.46	-----	(f)
----	-----	----	----	4.83	-----	(g)
851	177.3	674	.90	.90	Empty	(h)
1267	192.2	1075	1.44	1.44	Working	(h)
2781	235.	2546	3.41	3.41	Working	(i)
1532	183.3	1349	1.8	1.8	Empty	(i)
802	185.1	617	.83	.83	Empty	(j)
895	182.1	713	.95	.95	Working	(j)
2111	238.	1873	2.51	----	-----	(k)
1673	182.1	1491	2.00	2.00	-----	(l)
----	-----	----	----	.51	Working	(m)
2986	294.6	2691	3.61	----	-----	(n)
1673	182.1	1491	2.00		-----	(l)
----	-----	----	----	1.61	Working	(o)
1995	217.1	1778	2.38	----	-----	(p)
1673	182.1	1491	2.00	2.00	-----	(l)
----	-----	----	----	.38	Working	(q)
5522	533.2	4989	6.68	----	-----	(r)
5195	469.7	4725	6.32	----	-----	(s)
3557	313.4	3238	4.34	----	-----	(t)
----	-----	----	----	2.34	Working	(u)
----	-----	----	----	1.98	Working	(v)

Blacksmith Shop.

(a) Bull dozer (a) is the largest in the shop and is used to bend plow beams, form gang plow frames, steel pulverizer boxes, etc. The carriage has a stroke of 18 inches and makes eight strokes per minute. During the test, it was bending and twisting pole gang braces 1-3/8 inches by 5/16 inches. Motor was belted to machine.

(b) The counter shaft to which the bull dozer and shear are attached is 12 feet in length. Both belts were running on idle pulleys. Motor was belted to counter shaft. The bull dozer was tested first and shear last.

(b_1) Condition (b_1) is the same as (b) except that the bull dozer was working and the shear was idle.

(b_1) - (b) = Power required to run bull dozer working.

(b_2) This condition is the same as (b) except that the shear was working and the bull dozer was running idle.

(b_2) - (b) = Power required to run shear working.

(c) There are three bull dozers in the shop of the same size and design as bull dozer (c). They have a stroke of 12 inches and make 9 strokes per minute. During the test, bull dozer (c) was forming disc scrapers for pulverizers. The metal was 5/16 inch by 1 inch of high carbon steel.

(d) Shear (d) is operated by a cam on a shaft geared to the fly wheel shaft, the follower being the lever on the other end of which is the shear. The machine is of medium size and will cut stock up to 1-3/8 inches round of high carbon steel. It makes 24 strokes per minute. During the test, it was cutting off 3/4 inch round iron bars, two at a time. Every stroke during the run was utilized.

(e) This condition consists of the counter shaft and fan described in (f) and (g). The motor was belted to the counter shaft.

(f) The counter shafting for the fan consists of one shaft 30 feet long and another 12 feet long. The power to drive these shafts is taken from a third counter shaft which gets its power from the main line shaft under the blacksmith shop.

(e) - (f) = Power required to run the fan.

(g) Fan (g) is a Sturtevant of 20 inch diameter and 2500 revolutions per minute and is used for forge blasts for both the blacksmith and plow shops. This test was made out of working hours and an average number of tuyeres were opened.

(h) This condition includes the press and a short length of counter shaft to which the motor was belted. The press is a vertical one and is worked by means of a ten inch eccentric and a toggle joint. The machine was cutting off

ends and forming cultivator knives, the knives being hot. The table makes 16 strokes per minute.

(i) This condition includes a short length of counter shaft to which the motor was belted, and the machine, a vertical riveter, made by William White and Company, of Moline, Illinois. The cylinder contains rubber springs and the machine makes 540 blows per minute. The machine was riveting cultivator shovels during the test, there being two 3/8 inch rivets in each shovel. The machine appears to be taking a great deal of power but it must be taken into account that the belt used to connect the motor to the machine was old and of two different sizes, and this undoubtedly took up a great deal of power.

(j) Punch (j) is of small size and was made by William White and Company, of Moline, Illinois. It was belted direct to the motor. It has a stroke of 1-1/2 inch and makes 24 strokes per minute. Soft steel seat springs were being punched, the metal being 1/4 inch in thickness. There were six 7/16 inch holes in each piece. About every other stroke of the machine on the average, was "caught."

(k) This condition includes the counter shaft, described in (e), with the belts running on idle pulleys with trip hammer (m) working.

(l) Here, the shafting consists of one piece 28 feet long to which the motor was belted and a small counter

shaft 2 feet long. On the longer shaft are two medium sized trip hammers and a small bolt-threading machine. The belt to the bolt-threading machine was on the idle pulley at all times, the machine not being used. A trip hammer is belted to the short counter shaft. All three hammers are of about the same size, two of them being exactly alike. All belts were running to idle pulleys.

(k) - (l) = Power required to run trip hammer (m)

(m) Trip hammer (m) is connected to the short length of counter shaft and consists of a horizontal wooden beam properly cushioned with rubber and operated by an eccentric. The machine was drawing out cultivator shovels, fairly heavy work and was making about 260 blows per minute.

(n) is the same as (k) except that the trip hammer (o) was working instead of (m).

(n) - (l) = Power required to operate trip hammer (o).

(o) Trip hammer (o) is belted to the north end of the longer counter shaft. This is of a different type, being vertical. Motion is imparted by an eccentric to a steel spring arc, the ends of which are bound with leather bands. From these leather bands hangs the hammer, the motion being suitably guided by grooved guides. The machine was forming cultivator seat holder clips, very light work, and was mak-

ing about 150 -180 blows per minute. The increase in power over the two hammers is due to the fact that considerable power is used in raising the hammer each time while, in the case of the other two, the horizontal beam is more nearly balanced and the rubber cushions tend to give back more of the power.

(p) is the same as (k) except that trip hammer (q) was working instead of (m).

(p) - (l) = Power required to operate trip hammer (q).

(q) Trip hammer (q) is of the same size and type as (k). It was delivering about 150 blows per minute. The work was welding rings of 3/8 inch round iron, very light work.

(r) Condition (r) consists of a counter shaft 24 feet long, to which motor was belted. From it are belted one polishing machine, two emery wheels and a small fan, the power to run which is included in that of the counter shaft. The polishing wheel was worked by one man while the two emery wheels were running idle.

(s) This condition differs from (r) in that one emery wheel was being worked while the other emery wheel and the polishing machine were running empty.

(t) This condition consists of the shafting and machines running empty, as described in (r). It is the actual

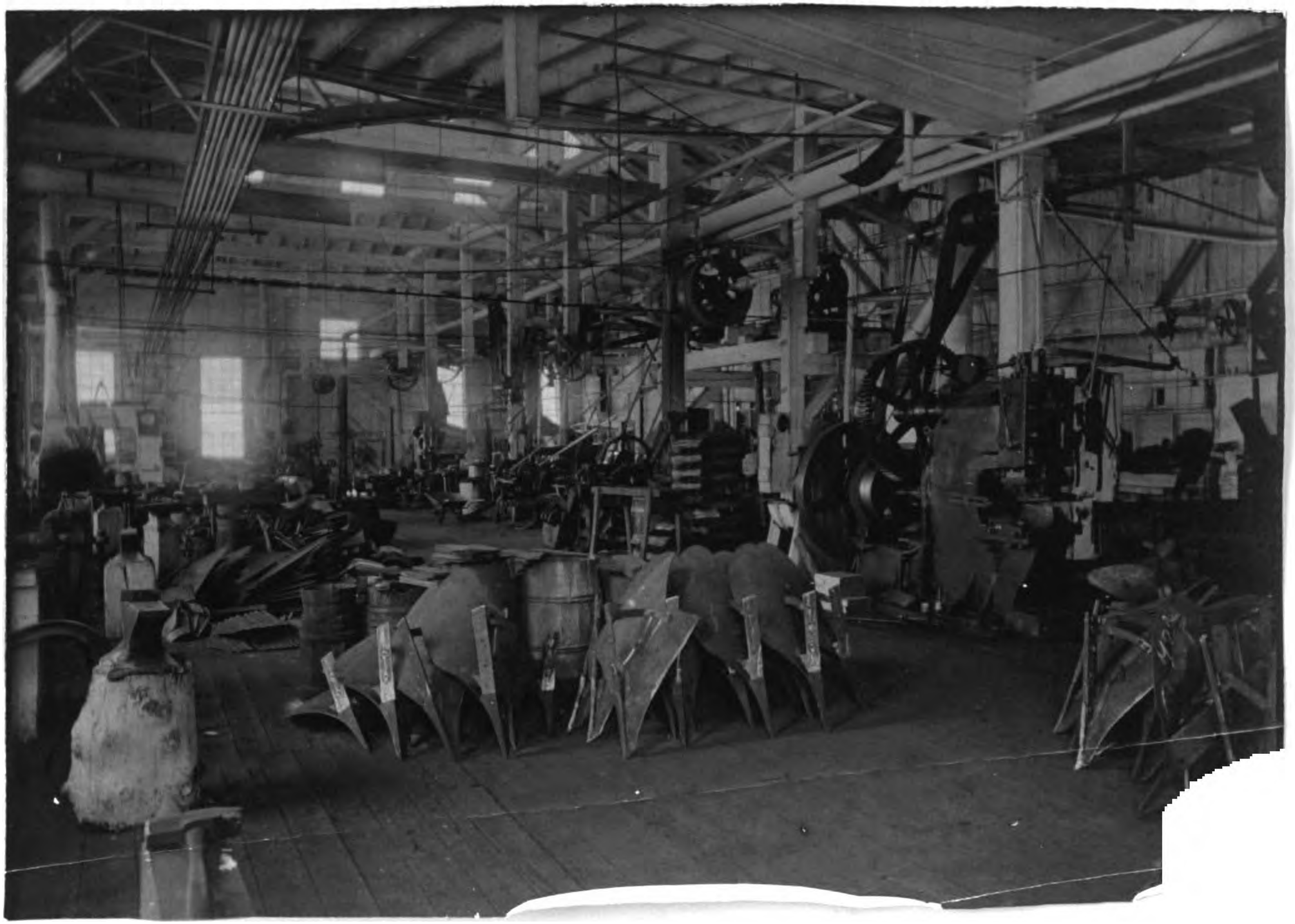
friction in shafting, belts, etc.

(r) - (t) = Power consumed in doing actual work and not in running the wheel working.

(s) - (t) = Power consumed in doing actual work of grinding and does not include the friction of the machine.

(u) Polishing wheel (u) consists of an ordinary 4 foot shaft, two-bearing polishing wheel. A polishing wheel of 12 inch diameter can be used at both end of the shaft. They revolve at 2000 R.P.M. The machine was being used to polish cultivator shovels.

(v) Emery wheels (v) are very much like the polishing wheel and make 1350 revolutions per minute. All three machines are belted from the counter shaft overhead and can be run separately or together.



Plow Shop, Looking South.

Plow Shop.

Instrument Readings.

	Speed	Motor Loaded				Mot
Name of Machine	Motor	Arm.C	Arm.V	Field C	Line V	Emp Arm
Drop ham. & line shaft	723	19.1	223	.96	237	2.
Drop ham. & line shaft	751	6.75	230	.96	237	3.
Line shaft alone	736	6.35	223	.97	235	2.
Drop hammer	---	------	---	---	---	---
Drop hammer	---	------	---	---	---	---
Emery wheel,l.& c. shafts	840	15.75	217	1.0	231	3.
Emery wheel,l.& c. shafts	820	10.2	227	1.0	236	3.
Line shaft alone	736	6.35	223	.97	235	2.
Emery wheel	---	------	---	----	---	---
Emery wheel	---	------	---	----	---	---
Shear & line shaft	790	7.33	226	1.0	235	3.
Line shaft alone	736	6.35	223	.97	235	2.
Shear	---	-----	---	----	---	---
Polishing wheels	652	24.0	220	.95	229	2.
Polishing wheels	675	16.2	218	.99	232	2.
Emery wheel set & c. shaft	651	27.0	207	.98	220	3.
Emery wheel set & c. shaft	685	16.3	215	1.0	227	3.
Bradley cush'n'd trip ham.	495	52.8	129	.90	219	[illegible]
Bradley cush'n'd trip ham.	547	9.00	171	.97	232	2.
Grind stone	332	28.0	147	.99	226	2.
Grind stone	327	11.0	113	1.0	235	3.
Big punch	560	7.50	167	.98	232	3.
Big punch	546	6.50	174	1.0	234	3.
Group machs. & l. shaft	740	19.0	194	.96	227	2.
Group machs. & l. shaft	765	14.8	206	.97	228	2.

Plow Shop.

	Watts		Horse-Power			
Total consumed	Motor loss	Delivered by motor	Delivered by motor	Consumed by mach.	Machine conditions	See Index Refer.
4488	311.8	4176	5.61	----	------	(a)
1779	174.2	1605	2.15	----	------	(b)
1643	194.6	1468	1.97	----	------	(c)
----	------	----	----	3.64	Working	(d)
----	------	----	----	0.18	Idle	(d_1)
3651	276.2	3375	4.52	----	------	(e)
2555	213.0	2342	3.14	----	------	(f)
1644	174.6	1469	1.97	----	------	(g)
----	------	----	----	2.55	Working	(h)
----	------	----	----	1.17	Empty	(i)
1894	190.9	1703	2.28	----	------	(j)
1645	174.6	1470	1.97	----	------	(k)
----	------	----	----	0.31	Working	(l)
5493	399.6	5093	6.82	6.82	Working	(m)
3747	276.8	3470	4.65	4.65	Empty	(n)
5806	476.4	5330	7.14	7.14	Working	(o)
3698	282.9	3415	4.57	4.57	Empty	(p)
7045	340.6	5704	7.64	7.64	Working	(q)
1763	192.2	1571	2.11	2.11	Idle	(r)
4339	501.9	3837	5.14	5.14	Working	(s)
1478	219.8	1258	1.68	1.68	Empty	(t)
1479	185.4	1294	1.73	1.73	Working	(u)
1364	185.8	1178	1.58	1.58	Empty	(v)
3905	309.9	3595	4.82	4.82	Working	(w)
3272	251.7	3070	4.11	4.11	Idle	(x)

Plow Shop.

In getting the power consumed by the machines in the plow shop, a portion of the line shaft was uncoupled and the motor was belted to a pulley on this section of the shaft.

(a) In this condition, the foot lever operating the drop hammer was kept down so that the hammer fell continuously.

(b) In condition (b), the hammer was not dropping. The power was absorbed by the gears that raise the hammer, the belt from the main shaft to the hammer and the belt and inertia wheel of the small shear.

(c) This includes the friction of the counter shaft, the friction in belt running to the idle pulley of the hammer and also that of a belt and inertia wheel of a small shear.

(a) - (c) = Power required to work the hammer and overcome the friction of a belt and inertia wheel on a small shear.

(b) - (c) = Power required to turn the gears of the drop hammer.

(d) The machine "working" means that the hammer was dropping continuously. A board was placed on the anvil so that no injury was done it. This had the same effect as a

piece of work in the dies would have had, as the work done consists simply in raising the hammer. The die weighed about 1300 or 1400 pounds and the hammer was delivering about 50 blows per minute.

(d') consists of pinion and heavy spur gear for operating the drop hammer.

(e) In this condition, the section of line shaft, a small counter shaft, and a "working" emery wheel were in operation. The belt and inertia wheel of the small shear were also running.

(f) This condition is the same as (e) except that the wheel was running empty.

(g) In this condition, the line shaft alone was running. In connection with this section of line shafting, a belt was running to the idle pulley on the hammer and also one to a small shear, which belt was turning an inertia wheel.

(e) - (g) = Power required to run the small counter shaft and the emery wheel "working."

(f) - (g) = Power required to run small counter shaft and emery wheel running "empty."

(h) This includes the small counter shaft and the emery wheel "working." The emery wheel is of ordinary size with a shaft 4 feet, 6 inches long, making about 1380 revolutions per minute. Some case-hardened plow pieces were being constantly pressed against the wheels for "working" con-

ditions.

(i) This includes the small counter shaft and the emery wheel running empty.

(j) This includes the same section of line shaft and the small shear working.

(k) This condition is that of the line shaft section alone, including that of the belt and inertia wheel of the small shear.

(j) - (k) = Power consumed by shear in doing work only and not in running shear working.

(l) Shear (l) is of small size and consists of a lever, to one end of which power is applied by means of a cam and on the other end of which the cutting dies are fastened. The machine makes about thirty-five revolutions per minute. Some plow land-sides were being cut, every stroke of the machine being "caught."

(m) In this case, the motor was belted direct to the small counter shaft, which was of six foot length. The polishing wheel or machine consists of a six foot, six inch shaft held firmly in two bearings. It revolves at a speed of about 1700 revolutions per minute. There are three machines like this. It is used for polishing finished plows and also plow parts, as shears, mold boards, land-sides, etc. The wheels are 20 inches in diameter with a 4 inch face, being made of several layers of heavy cotton, securely bound

with wire. The circumference is then covered with glue and the wheel rolled in emery dust. There are two wheels on each machine, though in our test, only one was being used, the work being that of polishing plow shares.

(n) This condition is the same as (m) except that no work was being done by the machine.

(o) This consists of a counter shaft 50 feet long,to which the motor was belted,and six emery wheels. These emery wheels are of small size, each shaft being three feet long. There is a wheel at each end, though but one was being used at the time of our test. These wheels are used by plow fitters and there are seldom more than three in use at any one time. The work is generally light. During the test, there was a man at each machine doing average work.

7.14 ÷ 6 = 1.19 which is the power consumed by a single wheel working.

(p) This condition is the same as (o) except that no work was being done on the wheels.

4.57 ÷ 6 = .76 H.P. which is the power consumed by a single emery wheel when running empty.

(q) Difficulty was experienced in making this test. Motor was belted to counter shaft. No pulleys were at hand to get the desired speed. Finally, one was obtained which would give the required speed but it was of wood and had a face of but five inches. The belt necessary to pull the load

was a six inch one and of course it was impossible to get the proper amount of contact with the six inch belt on a five inch pulley. When the load was thrown on, the belt would slip and the speed could not be kept high enough. This test was made during working hours and we were unable to meet the conditions as we would have wished. This trip hammer, called the Bradley Cushioned Hammer, is a very heavy one, being of the long, horizontal type and heavily cushioned with rubber cushions. It delivers an average of 275 blows per minute. During the test, the work was plating plow shares, very heavy work.

(r) This condition implies only running the counter shaft up to speed (in this case about 35 revolutions above speed).

(s) The motor was belted direct to the grindstone. The stone is originally six feet in diameter with an eight inch facebut it was worn down to five feet, four inches when the test was made. The stone makes about 110 revolutions per minute and is used for grinding plow faces, etc. The stone had been newly dressed when we tested it and was cutting good. The power consumed is high because the work is being done at such a distance from the center of the wheel.

(t) Same conditions as (s) except that no work was being done, the power only tending to keep the wheel in motion.

(u) Punch (u), made by the Wais and Roos Punch and Shear Company, of Cincinnati, Ohio, is about the heaviest around the works and was supposed to take considerable power on its heavy work. It had a throat of 16 inch height and 30 inch depth and is used for heavy work on plow parts, etc. It gives about 25 strokes per minute. The motor was belted direct. The work was considered heavy and consisted in punching frogs for land sides from 1/4 inch metal. The sheared perimeter was 24 inches. The inertia of the fly-wheel was sufficient to carry the die through; consequently the power consumption was low.

(v) The conditions are the same as (u) except that the punch was running empty.

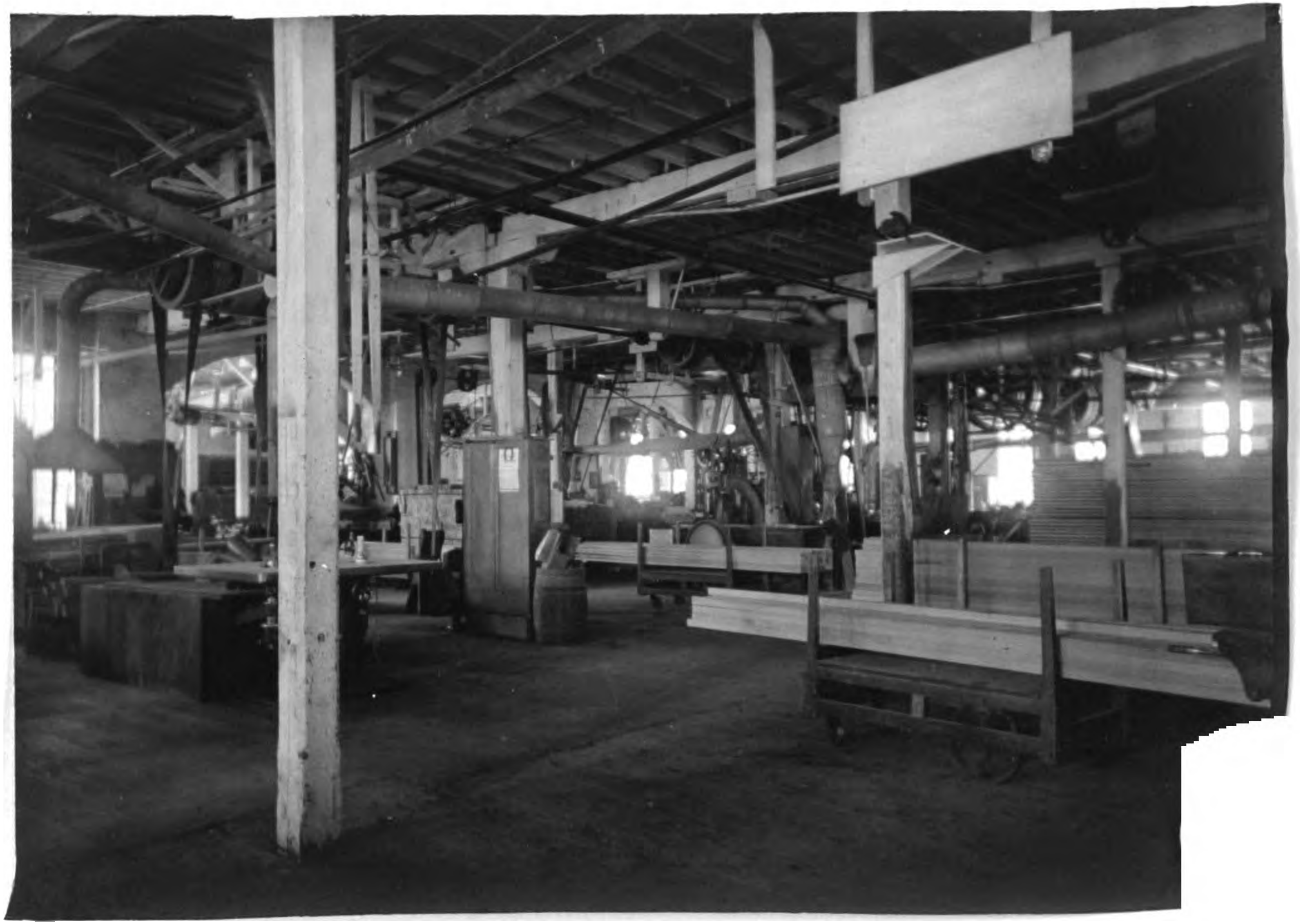
(w) After making the tests of the machines on the particular section of shafting which had been uncoupled, the coupling to the north of the drop hammer was again coupled up, leaving the other one uncoupled. The motor was again started up, all the machines on the shaft were started up empty and readings taken. The machines on this shaft are:

Two drill presses,
One punch,
Two milling machines,
One jointer,
One emery wheel (small, for grinding drills),
Two 8 inch belts running on idle pulleys on polishing machines,

One six inch belt running on idle pulley on big punch.

All of the above machines are of small size.

(x) Condition (x) only differs from (w) in that the machines were all running with the belts on idle pulleys.



Wood Shop.

Wood Shop.

Instrument Readings.

	Speed	Motor Loaded				Motor Empty
Name of Machine	Motor	Arm.C	Arm.V	Field C	Line V	Arm. C
I	582	39.00	195	1.0	220	2.90
II	613	18.75	195	1.0	230	2.60
Main shaft	628	17.00	200	1.0	232	2.93
Rip saw	---	-----	---	---	---	----
Rip saw	---	-----	---	---	---	----
IV	636	27.50	190	.95	224	2.75
V	629	26.60	194	.95	226	2.93
III	628	17.00	200	1.0	232	2.93
Shaper	---	-----	---	----	---	----
Shaper	---	-----	---	----	---	----
VI	627	20.00	194	.95	230	3.00
III	628	17.00	200	1.0	232	2.93
Cross cut saw	---	-----	---	----	---	----
VII	588	24.50	197	.95	225	3.00
VIII	623	20.50	193	.95	228	2.90
III	628	17.00	200	1.0	232	2.93
Jointer	---	-----	---	----	---	----
Jointer	---	-----	---	----	---	----
IX	601	21.75	189	.94	226	3.00
X	633	20.50	195	.95	228	3.00
III	628	17.00	200	1.0	232	2.93
Wood lathe	---	-----	---	----	---	----
Wood lathe	---	-----	---	----	---	----
XI	620	24.00	196	.93	226	3.00
III	628	17.00	200	1.0	232	2.93
Rotary plane	---	-----	---	----	---	----
XII	646	17.50	202	.95	230	3.00
III	628	17.00	200	1.0	232	2.93
Mortiser	---	-----	---	----	---	----
XIII	621	43.00	187	.86	217	3.00
III	628	17.00	200	1.0	232	2.93
Fan	---	-----	---	----	---	----

Wood Shop.

Watts			Horse-Power			
Total consumed	Motor loss	Delivered by motor	Delivered by motor	Consumed by mach.	Machine condi- tions	See Index Refer.
7830	826.3	7004	9.39	----	-----	(I)
3890	317.6	3572	4.79	----	-----	(II)
3632	292.3	3340	4.48	----	-----	(III)
----	-----	----	----	4.91	Working	(a)
----	-----	----	----	.31	Empty	(b)
5440	476.6	4963	6.65	----	-----	(IV)
5380	457.0	4923	6.61	----	-----	(V)
3632	292.3	3340	4.48	----	-----	(III)
----	-----	----	----	2.17	Working	(c)
----	-----	----	----	2.13	Empty	(d)
4098	324.1	3774	5.05	----	-----	(VI)
3632	292.3	3340	4.48	----	-----	(III)
----	-----	----	----	0.57	Empty	(e)
5044	410.2	4634	6.22	----	-----	(VII)
4176	332.7	3893	5.15	----	-----	(VIII)
3632	292.3	3340	4.48	----	-----	(III)
----	-----	----	----	1.74	Working	(f)
----	-----	----	----	0.67	Empty	(g)
4327	371.6	3955	5.29	----	-----	(IX)
4216	332.2	3883	5.20	----	-----	(X)
3632	292.3	3340	4.48	----	-----	(III)
----	-----	----	----	0.81	Working	(h)
----	-----	----	----	0.72	Empty	(i)
4917	393.5	4523	6.07	----	-----	(XI)
3632	292.3	3340	4.48	----	-----	(III)
----	-----	----	----	1.59	Empty	(j)
----	283.5	3474	4.66	----	-----	(XII)
3632	292.3	3340	4.48	----	-----	(III)
----	-----	----	----	0.18	Empty	(k)
8232	922.8	8309	11.12	----	-----	(XIII)
3632	292.3	3340	4.48	----	-----	(III)
----	-----	----	----	6.64	-----	(l)

Wood Shop.

Instrument Readings.

	Speed		Motor Loaded			Mot
Name of Machine	Motor	Arm. C	Arm. V	Field C	Line V	Emp Arm
XIV	614	19.50	197	.95	231	2.
XV	636	17.75	201	.95	232	2.
III	628	17.00	200	1.00	232	2.
Band saw	---	-----	---	----	---	---
Band saw	---	-----	---	----	---	---
XVI	617	32.70	195	.92	222	2.
III	628	17.00	200	1.00	232	2.
Neck yoke lathe	---	-----	---	----	---	---
XVII	623	48.00	189	.89	212	3.
XVIII	623	29.30	193	.90	221	2.
XX	614	25.10	192	.90	222	3.
Rip saw	---	-----	---	---	---	---
Rip saw	---	-----	---	---	---	---
XIX	604	56.30	181	.85	209	2.
XX	614	25.10	192	.90	222	3.
Fan	---	-----	---	---	---	---
Planer	629	35.60	221	1.0	234	3.
Planer	689	26.50	227	1.0	238	3.
Planer	669	35.30	226	1.0	236	3.
Planer	687	20.50	223	1.0	238	3.
XX	614	25.10	192	.90	223	3.
III	628	17.00	200	1.00	232	2.
Counter shaft	---	-----	---	----	---	---

Wood Shop.

Watts			Horse-Power			
Total consumed	Motor loss	Delivered by motor	Delivered by motor	Consumed by mach.	Machine condi- tions	See Index Refer.
4060	314.9	3745	5.02	----	------	(XIV)
3792	286.1	3506	4.70	----	------	(XV)
3632	292.3	3340	4.48	----	------	(III)
----	------	----	----	0.54	Working	(m)
----	------	----	----	0.22	Empty	(n)
6581	604.1	5977	8.01	----	------	(XVI)
3632	292.3	3340	4.48	----	------	(III)
----	------	----	----	3.53	Empty	(o)
9269	1129.2	8149	10.9	----	------	(XVII)
5860	507.00	5353	7.18	----	------	(XVIII)
5020	408.50	4611	6.18	----	------	(XX)
----	------	----	------	4.72	Working	(p)
----	------	----	------	1.00	Empty	(q)
10298	1473.5	8824	11.83	----	------	(XIX)
5020	408.5	4611	6.18	----	------	(XX)
----	------	----	----	5.67	------	(r)
8102	727.6	7374	9.88	----	Working	(s_1)
6253	470.9	5782	7.75	----	------	(s_2)
8214	684.6	7529	10.1	----	------	(s_3)
4808	349.9	4458	5.98	----	Empty	(s)
5020	408.5	4611	6.18	----	------	(XX)
3632	292.3	3340	4.48	----	------	(III)
----	------	----	----	1.70	------	(t)

Wood Shop.

The same method was used for testing the separate machines of this shop as was used in the plow shop and foundry, namely, that of belting the motor to the main shaft and then throwing on the machines one at a time.

A large counter shaft in an adjoining room is driven by belt from the main shaft. The belt to this counter shaft was put on the idle pulley during the time of testing the machines in the main room and was thrown on later when the machines in the adjoining room were tested. The main shaft is 114 feet long and of several different sizes of shafting. There are a great many pulleys on this shaft, there being 72 tight and idle ones connecting to 16 small and one large counter shaft.

(I) Condition (I) consists of the main shaft with all belts running to idle pulleys and a rip saw working.

(II) Same as (I) except that the rip saw was running empty.

(III) This includes the main shaft alone with all belts on idle pulleys and no machines either empty or working.

(I) - (III) = Power consumed by the rip saw working.

(II) - (III) = Power consumed by the rip saw running empty.

(IV) Main shaft with all belts on idle pulleys and shaper working.

(IV) - (III) = Power consumed by shaper working.

(V) Main shaft with all belts on idle pulleys but with shaper running empty.

(V) - (III) equals power consumed by shaper running empty.

(VI) Main shaft with all belts on idle pulleys and small cross-cut saw running empty.

(VI) - (III) = Power consumed by cross-cut saw running empty.

(VII) Main shaft with all belts on idle pulleys and jointer working.

(VII) - (III) = Power consumed by jointer working.

(VIII) Main shaft with all belts on idle pulleys and jointer running empty.

(VIII) - (III) = Power consumed by jointer running empty.

(IX) Main shaft with all belts on idle pulleys with wood lathe working.

(IX) - (III) = Power consumed by wood lathe running with work in machine.

(X) Main shaft with all belts on idle pulleys and wood lathe running empty.

(X) - (III) = Power consumed by wood lathe running empty.

(XI) Main shaft with all belts on idle pulleys and rotary planer running empty.

(XI) - (III) = Power consumed by rotary planer operating empty.

(XII) Main shaft with all belts on idle pulleys and mortiser running empty.

(XII) - (III) = Power consumed by mortiser running empty.

(XIII) Main shaft with all belts on idle pulleys and with big fan near center of shop in operation.

(XIII) - (III) = Power consumed by fan.

(XIV) Main shaft with all belts on idle pulleys with band saw working.

(XIV) - (III) = Power consumed by band saw working.

(XV) Main shaft with all belts on idle pulleys and band saw running empty.

(XV) - (III) = Power consumed by band saw running empty.

(XVI) Main shaft with all belts on idle pulleys with neck yoke turning lathe running empty.

(XVI) - (III) = Power consumed by neck yoke turning lathe running empty.

(VII) Main shaft and counter shaft in adjoining room with all belts on idle pulleys, with rip saw in adjoining

room working.

(XVII) -(XX) = Power consumed by rip saw in adjoining room working.

(XVIII) Main shaft and counter shaft in adjoining room with all belts on idle pulleys with rip saw in same room running empty.

(XVIII) - (XX) = Power consumed by rip saw in west room running empty.

(XIX) Main shaft and counter shaft in adjoining room with all belts on idle pulleys. Small fan over planer in west room in operation.

(XIX) - (XX) = Power consumed by small fan over planer.

(XX) Main shaft and counter shaft in west room with all belts on idle pulleys.

Wood Shop.- Continued.

(a) The work done during the testing of this machine (described in (b)) consisted in ripping some 2 inch hardwood planks.

(b) The rip saw (b) is an iron frame machine, belted to the main shaft. It takes a circular saw, 11 inch in diameter, which revolves at 1950 R.P.M.

(c) The work done during the test of this machine (described in (d)), consisted in shaping wagon tongues, which is very light work. This will be seen when machine "Working" and machine "Empty" are compared.

(d) Shaper (d) is of ordinary size with a steel table which can be tilted to any angle. The cutting blades make 5500 R.P.M.

(e) Saw (e) takes a saw of 12 inches in diameter which revolves 2400 times a minute. The saw is moved backward and forward by hand. As it took but a few secondsto cut through the wood, we were unable to obtain any data of the machine "Working," as there were four readings of the instruments to be taken. So the machine "empty" condition only is recorded.

(f) The work done during the test of the jointer, (described in (g)) consisted in taking a 1/8 inch cut from pine boards, 8 inches wide, light work.

(g) Jointer (g) has a table 7 feet long by 1 foot 8 inches wide. The cutting tool makes about 4500 R.P.M.

(h) Lathe (i), described in (i), was turning whiffle trees of hard wood, light work, as the work in a wood lathe generally is. The power consumed is nearly all used in keeping up the speed of the machine which was running at about 1500 R.P.M. during the test.

(i) Wood lathe (i) has a bed of 12 feet length and will take a piece of stock 7 feet in length between its centers. It has four speeds, the highest being 1500 R.P.M.

(j) Rotary planer (j) consists of a vertical shaft with two cutting tools at a radius of 12 inches from the center. These revolve at 1200 revolutions per minute and can be adjusted up and down. The machine is used to plan off the edges of from six to ten pieces of hard wood stock clamped firmly to a moving table, which travels on wyes 24 feet in length. The counter shaft operating this machine is driven by a quarter-turn belt from the main shaft.

(k) Machine (k) consists of a vertical mortiser operated by a five inch eccentric and delivering 265 blows per minute. Work was put in the machine but the tool broke before the speed could be adjusted sufficiently to take readings. So readings were taken "empty." The machine is used for mortising rectangular holes in wagon tongues, etc.,

and consumes much more power than is required to run the machine "empty."

(l) Fan (l) is a Sturtevant of 40 inch diameter; makes about 2100 R.P.M. and draws shavings, dust, etc., from the saws, sander, shaper, jointer, etc., and delivers them in the boiler room.

(m) Band saw (n), described in (n), was sawing ordinarily through two inch pine boards. The average thickness of stock cut was about 1-1/2 inches.

(n) Band saw (n) consists of a band saw of 3/8 inch width running over two feet, 9 inch wheels, 4-1/2 feet between centers.

(o) Neck yoke turning lathe (o) has about 5 feet of knives properly ground to make the right shape of neck yoke and makes in the neighborhood of 2200 revolutions per minute. The power for this machine seems high. But it must be remembered that the machine had not been used for nearly a year and the bearings were gummed up, etc. This accounts for a goodly part of the "power consumed."

(p) Rip saw (q), described in (q), was engaged in ripping 3 inch elm planks. The planks were 16 feet long and the time taken to rip each plank was amply sufficient to get the speed down constant and to get the readings.

(q) Rip saw (q) does the heaviest work of the shop. The heavy work is 3 inches thick and often the stock is taken

direct from the yards and is not always very dry. It takes a 7 inch belt to pull it, uses a 10 inch circular saw, the saw making about 1950 R.P.M.

(r) The small fan over the planer in the west room is a Sturtevant of 2 feet diameter and makes 2400 R.P.M. It is used to draw up shavings, dust, etc., from the planer and saws in the west room of the shop.

It was thought that the planer took considerable power. As the motor was of but 15 H.P., it was thought that the line shaft, counter shaft, and planer would prove too heavy a load so the motor was belted direct to the planer counter shaft and the belt and loose pulley on the planer taken care of so as not to burn up from friction. Some difficulty was experienced, due to the slipping of belts but this was finally overcome. The blades of the planer were in fairly good condition.

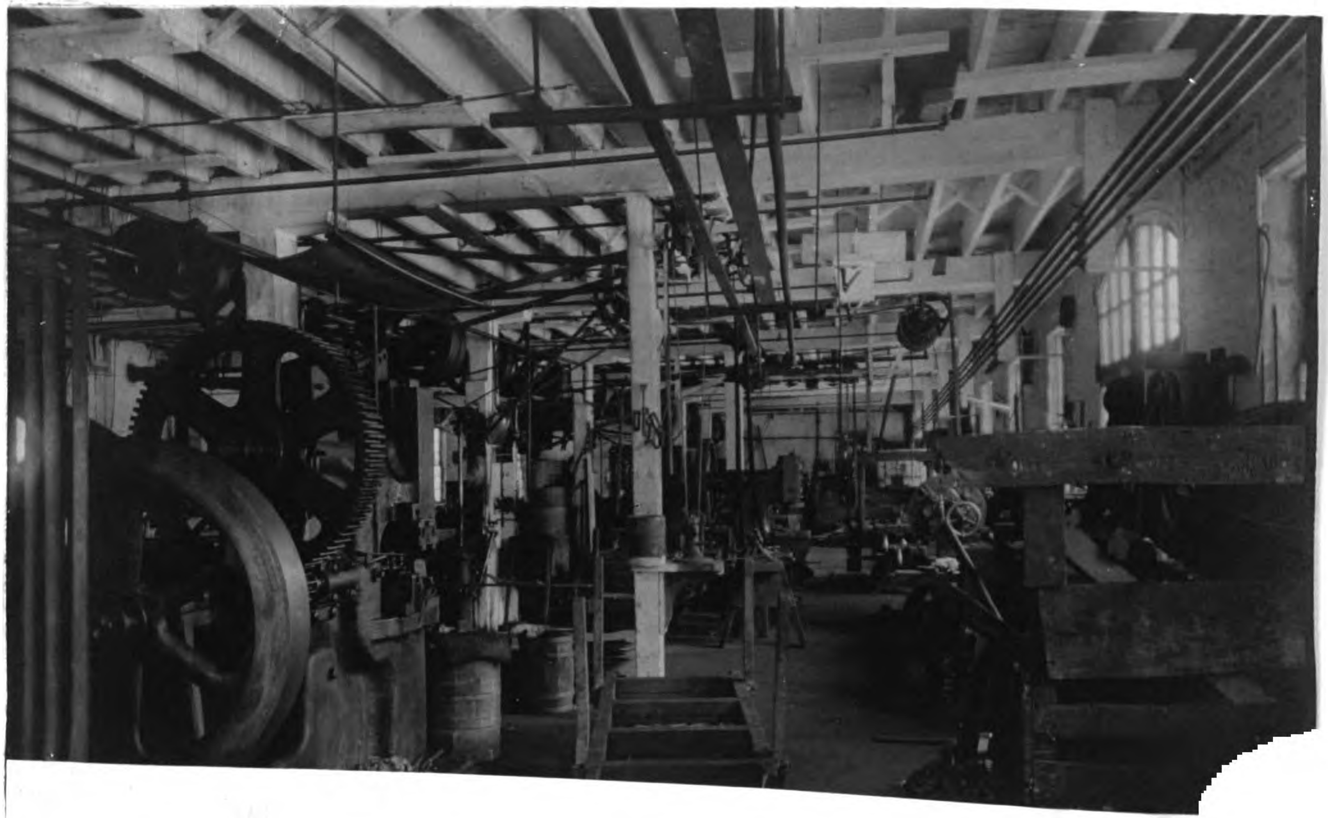
(s_1) The work for condition (s_1) was planing some 6 inch wide elm boards. The cut was from 1/16 inch to 1/4 inch in thickness. The boards were fed through the machine in quick succession.

(s_2) The stock planed for this test was the second cut of the elm boards, the cut being 1/16 inch deep. The boards were fed through in quick succession, two at a time.

(s_3) The work for this condition consisted in taking a 1 inch cut from cotton-wood planks with a width of from 1 to 2 feet.

(s) The machine is made by the C. A. Woods Machine Company, of Boston, Massachusetts, and will take cuts up to 1/2 inch in depth. The blades are three in number and revolve at 3300 R.P.M.

(t) The counter shaft is 78 feet in length and is situated in the west room adjoining the main room of the wood working department. The distance between this shaft and the main shaft is 36 feet.



Machine Shop, First Floor.

Machine Shop.

Instrument Readings.

	Speed	Motor Loaded				Vo
Name of Machine	Motor	Arm.C	Arm.V	Field C	Line V	Em Ar
I	606	22.00	210.5	.95	232	2.
II	577	18.00	190.0	.95	231	2.
Tool room & room underneath--		-----	-----	---	---	--
III	533	37.00	191.0	.93	229	2.
I	606	22.00	210.5	.95	232	2.
Second floor & tool room	---	-----	-----	---	---	--
IX	606	22.00	191.0	.95	232	2.
IV	572	17.50	180.0	.94	228	2.
Second floor	---	-----	-----	---	---	--
V	598	19.30	229.o	.95	234	2.
IV	572	17.50	180.0	.94	228	2.
Combined shear & gang punch--		-----	-----	---	---	--
VI	564	23.5	180.	.94	231	3.
IV	572	17.5	180.	.94	228	2.
Punch	---	----	----	---	---	-
VII	600	21.0	187.	.95	230	2.
IV	572	17.5	180.	.94	228	2
Engine lathe	---	----	----	---	---	-
VIII	540	37.9	184.	.90	222	3.
IV	572	17.5	180.	.94	228	2
Elevator	---	----	----	---	---	-
IV	572	17.5	180.	.94	228	2
I - II	---	----	----	---	---	-
First floor	---	----	----	---	---	-

Machine Shop.

Watts			Horse-Power			
Total consumed	Motor loss	Delivered by motor	Delivered by motor	Consumed by mach.	Machine condi-tions	See Index Refer.
4851	356.4	4495	6.02	----	-----	I
3640	290.5	3350	4.49	----	-----	II
----	-----	----	----	1.53	Idle	(a)
7280	736.0	6544	8.77	----	-----	III
4851	356.4	4495	6.02	----	-----	I
----	-----	----	----	2.75	Empty	(b)
4851	356.4	4495	6.02	----	-----	I
3364	280.0	3084	4.14	----	-----	IV
----	-----	----	----	1.88	Idle	(b)
4642	311.7	4330	5.80	----	-----	V
3364	280.0	3084	4.14	----	-----	IV
----	-----	----	----	1.66	Working	(c)
4441	386.6	4060	5.44	----	-----	VI
3364	280.0	3084	4.14	----	-----	IV
----	-----	----	----	1.30	Working	(d)
4149	341.7	3807	5.10	----	-----	VII
3364	280.0	3084	4.14	----	-----	IV
----	-----	----	----	.96	Working	(e)
7175	756.5	6418	8.60	----	-----	VIII
3364	280.0	3084	4.14	----	-----	IV
----	-----	----	----	4.46	Going up	(f)
3364	280.0	3984	4.14	----	-----	IV
----	-----	----	1.53	----	-----	---
----	-----	----	----	2.61	Idle	(g)

Machine Shop.

But one setting of the motor was required to test this department. The third floor shaft is driven by belt from the second floor shaft and this, in turn, from the first floor shaft. So the motor was belted to the first floor shaft. The belts are held taut against the pulleys by idlers or tighteners which could be removed, thus enabling us to "cut out" floors at will.

The data for the third floor are not very reliable and have been cut out. The reason for this is that, when the belt connecting the motor to the line shaft was laced, the ends were lapped over a trifle and, as the lapped portion passed over the motor pulley, the belt would slip and consequently the ammeter needle did not remain steady. So "guessing" at the average current was resorted to and the results, when worked up, show that the guesses were wild ones. But, as the power required to run the third floor is very small, and, for our purposes, unimportant, this is immaterial. After running for a few minutes, this difficulty disappeared and reliable readings were obtained.

I. All belts on first and second floors, tool room and room below running on idle pulleys, with third floor "cut out."

II. All belts on first and second floors running on

idle pulleys. Third floor, tool room, and room below, including riveter in "long building", "cut out."

I - II = Power required to run tool room and the room underneath with all belts running on idle pulleys.

III. All belts on the first floor running on idle pulleys. Machines on second floor (including tool room), running empty. Third floor "cut out". All belts in room underneath running on idle pulleys.

III - I = Power required to overcome friction in machines "empty" on second floor (including tool room). This does not include friction in shafts or belting on second floor.

IV. This includes all belts on first floor, in tool room and room underneath running to idle pulleys. The second and third floors were "cut out."

I - IV = Power consumed in overcoming friction in main shafts, short counter shafts, and belts on second floor.

V. All belts on first floor, in tool room and room underneath running to idle pulleys, with combined shear and gang punch near north door working.

V - IV = Power consumed by combined shear and gang punch working.

VI. All belts on first floor, in tool room and room underneath running to idle pulleys with big punch at west end of shop working.

VI - IV = Power consumed by big punch working.

VII. All belts on first floor, and tool room and room underneath running to idle pulleys with big engine lathe working.

VII - IV = Power consumed by engine lathe working.

VIII. All belts on first floor, tool room and room underneath running to idle pulleys with elevator at northeast corner of building going up.

VIII - IV = Power consumed by elevator going up.

II - (Power required to overcome friction in second floor with belts running to idle pulleys) = Power required to overcome friction on first floor with all belts running to idle pulleys.

Machine Shop.- Continued.

(a) The shafting in the tool room consists of 32 feet of 2 inch shafting. The machines are:

Two drill presses,
One Yankee twist drill grinder,
One emery wheel,
One metal lathe.

None of these machines are of large size, being those of the average machine shop and are used for repairing small tools, etc. The power for tool room is transmitted by a belt through the floor from the shaft of the room below. This shaft is 40 feet long and 2 inches in diameter and has 5 counter shafts connected to it.The machines (not run at all during the test) are:

One boring mill,
One engine lathe,
One punch and shear combined,
One riveting machine in "long building,"
One 20-foot length of counter shaft,
Four short lengths of counter shafts.

The main shaft of this room is driven from the main shaft of the first floor.

(b) The shafting of the second floor is 90 feet long and 2-1/8 inches in diameter. There are 14 short lengths of

counter shaft. The machines are:

One friction drill,
One small drill press,
Two shapers,
Two milling machines,
One grindstone,
One planer,
Three iron lathes,
One nut-tapping machine,
Three drill presses,
One emery wheel,
One wood lathe (on third floor).

All machines are of small size.

(c) Combined shear and gang punch (c) is of fairly heavy size, making 22 strokes per minute. It was punching three 1/4 inch holes at a stroke through the 3/16 inch stock.

(d) Punch (d) is of medium size and makes about 26 strokes a minute. It was punching one 1/4 inch square and one 1/4 inch round hole in 1/4 inch stock.

(e) Engine lathe (e) will take a 15 inch piece of work and has a bed 20 feet long. It was taking a cut 1/8 inch deep on a piece of shafting 2-1/2 inches in diameter.

(f) Elevator (f), operated by a worm gear, is capable of raising two loaded wheel-barrows or a loaded truck

and makes the trip to the third floor in thirty seconds.

(g) The shafting of the first floor consists of 96 feet of 2-1/8 inch shafting, with 14 short lengths of counter shafting. The machines are:

One polishing wheel, (on floor above),
One emery belt, (on floor above),
One planer,
One punch,
Two combined punches and shears,
Two drill presses,
Two engine lathes,
Two tapping machines,
One grindstone,
One emery wheel,
One emery wheel (for grinding drills).

Most of the machines are of small size, the punches being of fairly moderate size. The power required to drive the first floor with belt on idle pulleys may seem large, but it must be remembered that the shaft has a great many belts connecting to counter shafts, that there are many bearings and, in several places, these are quite close to each other, and that the shaft has not been lined up for a long time.

Warehouse Machine Shop.

Instrument Readings.

	Speed	Motor Loaded				Motor Empty
Name of Machine	Motor	Arm.C	Arm.V	Field C	Line V	Arm. C
I	554	39.50	186	.99	223	2.90
IX	577	27.75	196	.95	225	2.92
Fan	---	-----	---	---	---	----
II	500	51.20	190	.95	215	2.85
III	595	28.20	199	.98	222	2.90
VI	550	23.50	204	.95	228	2.85
Polishing Wheel	---	-----	---	---	---	----
Polishing Wheel	---	-----	---	---	---	----
IV	585	38.20	193	.94	217	2.90
VI	550	23.50	204	.95	228	2.85
Elevator	---	-----	---	---	---	----
V	553	44.70	193	.93	215	2.85
VI	550	23.50	204	.95	228	2.85
Elevator	---	-----	---	---	---	----
VII	533	26.50	197	.95	224	2.80
VI	550	23.50	204	.95	228	2.85
Gang punch	---	-----	---	---	---	----
VIII	504	30.25	194	.94	224	2.75
VI	550	23.50	204	.95	228	2.85
"Foster Shaft"	---	-----	---	---	---	----
X	574	33.75	188	.92	223	3.10
IX	577	27.75	196	.95	225	3.10
Basement Machines	---	-----	---	---	---	----

Warehouse Machine Shop.

	Watts		Horse-Power			
Total consumed	Motor loss	Delivered by motor	Delivered by motor	Consumed by mach.	Machine conditions	See Index Refer.
7571	837.6	6733	9.01	----	-----	I
5654	483.3	5171	6.94	----	-----	IX
----	-----	----	----	2.07	-----	(a)
9944	1285.	8658	11.6	----	-----	II
5828	404.8	5423	7.28	----	-----	III
5011	389.8	4621	6.20	----	-----	VI
----	-----	----	----	5.40	Working	(b)
----	-----	----	----	1.08	Empty	(c)
7579	778.3	6801	9.12	----	-----	IV
5006	389.8	4616	6.18	----	-----	VI
----	-----	----	----	2.94	Going up	(d)
8827	1110.	7717	10.34	----	-----	V
5006	389.8	4616	6.18	----	-----	VI
----	-----	----	----	4.16	Going up	(e)
5433	454.7	4978	6.68	----	-----	VII
5011	389.8	4621	6.20	----	-----	VI
----	-----	----	----	.48	Working	(f)
6079	545.0	5534	7.42	----	-----	VIII
5011	390.0	4621	6.20	----	-----	VI
----	-----	----	----	1.22	Idle	(g)
6554	634.7	5919	7.94	----	-----	X
5654	484.5	5171	6.94	----	-----	IX
----	-----	----	----	1.00	Empty	(h)

Warehouse Machine Shop.

The power for operating the machines and shafting in this shop is transmitted by a shaft 235 feet long which lies under Center street, under the blacksmith shop and the plow polishing room of the plow shop, and extends 6 feet into the warehouse machine shop. It was thought that a single setting of the motor would give us readings that were sufficiently accurate, so a pulley, connecting to a small pump, was removed from the driving shaft and a larger one substituted, to which the motor was belted. The driving shaft was then uncoupled and readings taken.

To the driving shaft projecting through the south wall of the building, are belted two counter shafts. The one to the east, drives the machines in the basement and the polishing and grinding wheels used for pulverizer discs. The counter shaft to the west, drives the worm arrangements for two elevators and a counter shaft, to the end of which is belted a punch in a small adjoining room while a shaft on the floor above, running at right angles, is operated from this same counter shaft by a quarter-turn belt. This latter shaft will be spoken of as the "Foster" shaft.

For convenience, the lengths of the shafts will be given here. The driving shaft which projects six feet through the wall is the main shaft of the plant, being 235 feet long

and lying in a tunnel under the plow polishing room of the plow shop, the blacksmith shop,and Center street. The "east" counter shaft is 78 feet long. The "west" shaft is 34 feet long. The parallel counter shaft to the end of which the gang punch is attached, is 60 feet long, while the "Foster" shaft on the floor above is 90 feet long. All the shafting and bearings are new, and are lined up with a fair degree of accuracy.

I. In this condition, all belts were running to idle pulleys with the fan in operation. The polishing shaft was cut out.

II. Load I proved too heavy for the motor, as was shown by the blowing out of several fuses, so the fan and "Foster" shaft were cut out and the work resumed. Condition II implies the polishing shaft running and one polishing wheel being used, the other running empty.

III. Condition III is identically the same as II, except that the polishing wheels were revolving without doing work.

IV. Condition IV represents the "Foster" shaft and fan off, polishing counter shaft being also off. Elevator near south door going up with load.

V. Condition V is the same as IV, except that the elevator near the turn table was going up with load instead of the one near the south door.

VI. Condition VI includes the entire shafting with the exception of the "Foster" shaft. The fan was also cut out.

II - VI = Power consumed by polishing wheel when "working."

III - VI = Power consumed by polishing wheel "empty."

IV - VI = Power consumed by elevator (d) going up.

V - VI = Power consumed by elevator (e) going up with load.

VII. "Foster" shaft and fan cut out with gang punch in adjoining room "working."

VII - VI = Power consumed by gang punch "working."

VIII. Condition VIII includes everything except the fan. "Foster" shaft running.

VIII - VI = Power consumed by "Foster" shaft.

IX. Condition IX includes all shafting with belts running to idle pulleys. Fan off.

I - IX = Power consumed in operating fan.

X. This is the same as IX except that all the machines in the basement are running "empty."

X - IX = Power consumed in overcoming the friction in the machines. This does not include the friction in the shafting and belts of the room.

(a) Fan (a) is a Sturtevant 18 inches in diameter, revolving at 2000 R.P.M. It is used for removing emery particles from the wheels in the disc-grinding room.

(b) Polishing wheel, of this condition, is described under (c). The work during the test was polishing discs for harrows. 5.4 H.P. seems high, and this is quite possible as the workman seemed to be under the impression that he could bring so small a machine as our motor to a stop, and accordingly applied more pressure to the wheel.

(c) Polishing wheel (c), driven from a counter shaft overhead, is of the ordinary design being of a fairly large size. The wheels revolve at 1620 R. P. M.

(d) Elevator (d) is operated by the worm and worm wheel arrangement and will take two loaded wheelbarrows or a loaded truck on its platform. During the test, a loaded truck and a workman were being raised.

(e) Elevator (e) is operated in the same manner as (d). It is capable of raising three loaded trucks. During the test it is raising two loaded trucks and two men.

(f) Gang punch (f) is of medium size but, as it was doing light work, the power was consumed almost entirely in overcoming friction in the machine.

(g) "Foster" shaft (g) is described in the introduction to this department. It operates a lathe for roughing out castings. This lathe was not run during the test.

(h) To the shaft in the basement machine shop are belted five small counter shafts and the following machines, all of small size:

Three drill presses,

Two emery wheels (one for grinding drills),

One key seating machine,

One jointer.

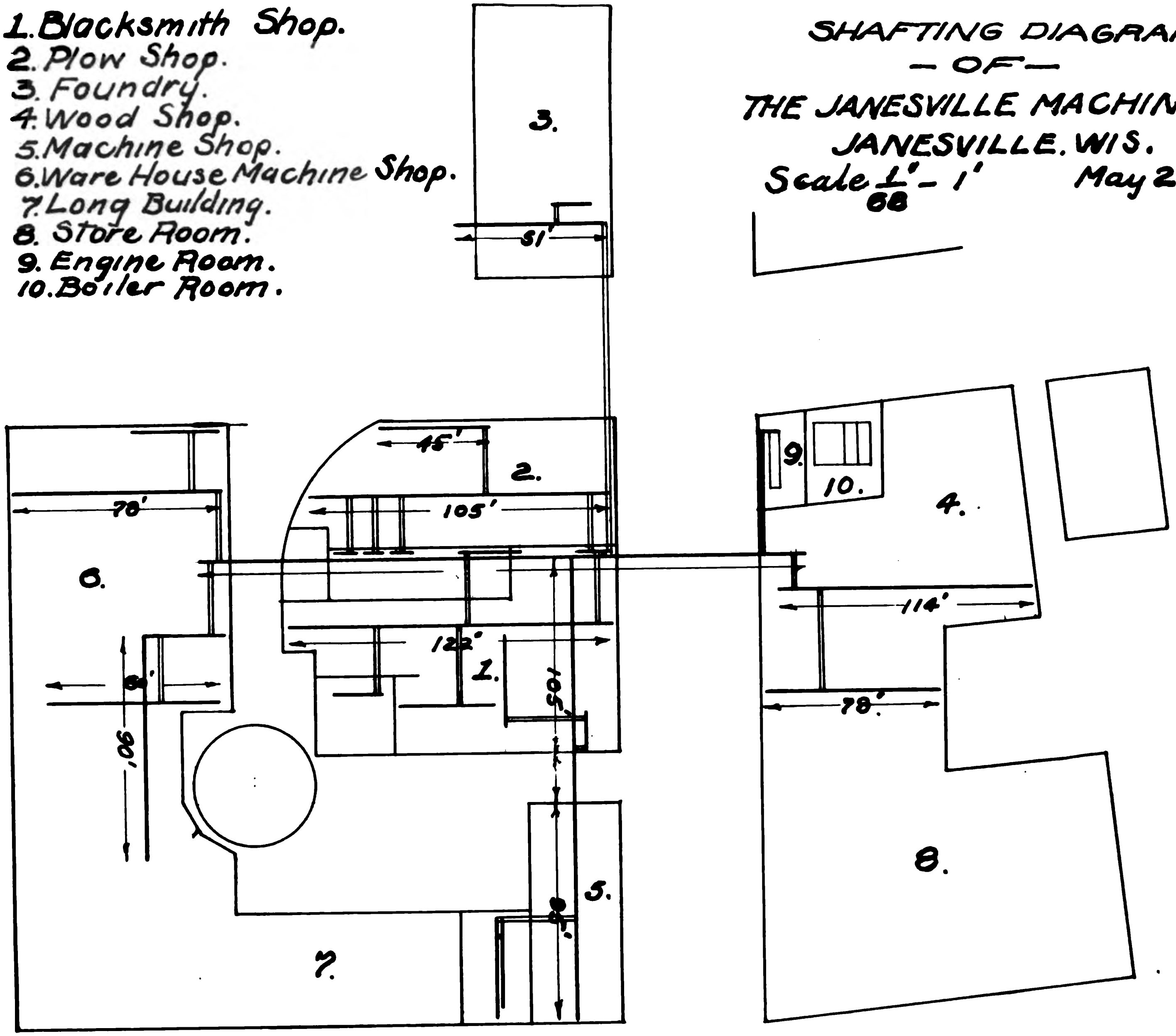
Results of Separate Machine Tests.

The results of these tests show that the iron-working machines, as punches, bull dozers, shears, etc., do not consume very much more power when "working" than when running "empty." The inertia wheels, which are provided on all these machines, have a reserve amount of energy which pulls the machines through without any perceptible additional pull on the belt. In the case of wood-working machines, however, this is not the case, as the results show. Putting work in these machines causes a greatly increased pull on the belt.

The fans consume considerable power because of their high running speed. The elevators also take a great deal of power, as do the large grindstones. The emery and polishing machines are also large power consumers, as are all of the machines running at high speeds.

It will be noticed, in the case of the foundry, that the rope drive takes about one-half of the power transmitted to this department and if the rattlers were all working, it would take about one-third.

SHAFTING DIAGRAM.
— OF —
THE JANESVILLE MACHINE CO.
JANESVILLE. WIS.
Scale 1'/68 - 1'   May 26, 03.



1. Blacksmith Shop.
2. Plow Shop.
3. Foundry.
4. Wood Shop.
5. Machine Shop.
6. Ware House Machine Shop.
7. Long Building.
8. Store Room.
9. Engine Room.
10. Boiler Room.

Installation of Motors.

In placing these motors, it was thought advisable to leave the machines in their present position as far as possible, to utilize the shafting of the departments as far as is practicable and to run only those machines with separate motors which are isolated and require long lines of shafting. However, the first cost of the installation will necessarily be large, and, to get the best benefit out of the electric drive, the machines should be grouped more, the number of lines of shafting decreased and the larger machines operated by separate motors. In nearly all cases, the speed of the shaft is too low to permit direct connection, but, where possible, this has been done. In such cases, the motor pulley can be removed and the shaft can be attached to the armature shaft by means of a flexible coupling.

All motors cited here are of the"open"type and in many cases, as of grinding rooms, foundry, etc., they will have to be protected from the dirt and dust. "Dust-proof" types could be furnished, but on account of the difficulty of dispelling the heat in the armature, the motors would have to be of double the horse-power of the "open" type. This would greatly increase the first cost, which is undesirable.

The cost of motors depends upon their speed. The

lower the speed, the more copper in their construction, hence the increase in price. Unless especially mentioned, the motors will be belted to shafts or machines and will run at their normal rated speed. The estimates on cost have been furnished by a reliable company, who give, as the data of their standard motors, on a 220 volt direct current circuit:

H.P.	Approx. Speed	Pulley Diam.	Pulley Face	Approx. Weight
3	1150	6	4	450
5	950	7	4	475
7.5	825	8	5	750
10	750	9	6	1100
15	725	10	8	1200
20	650	11	9	1550
25	650	12	10	1600
35	575	14	12	2200
50	550	18	14	3800

From this table, knowing the speed of shaft or machine to be driven, the pulley on shaft or machine may be computed. Approximate width of belt can also be figured from the fourth column. From the last column, can be figured the approximate cost of freight from factory, as the prices are f.o.b. cars.

In figuring the sizes of motors required, it is assumed that all shop machines are running at a maximum load. Several of the motors are of a slightly larger horse-power than the load requires. This was made necessary because of

the standard sizes of the motors made. On consulting the superintendent, it was deemed advisable, in several cases, to install motors which were larger than were required, in view of an increase in the number of machines to be driven by such motors.

The shops will be considered individually:

Foundry.

On an average, about 17 or 18 H.P. are consumed by all machines in this department. A 20 H.P. motor would pull all and all machines could be thrown on at once, but, on the other hand, assuming that the four rattlers are used only in the morning, while the blower is used only in the afternoon, a 10 H.P. motor would do the work easily, as both the rattler shaft and blower take in the neighborhood of 5 H.P. each. But it was thought safest, as the rattlers and blower are occasionally used at the same time, to pull the shaft with a 10 H.P. and the blower with a 7-1/2 H.P. motor. Installing these two motors in this department would save the constant loss which is going on in the rope drive. The results of the test show this loss to amount to nearly 6 H.P., which is by no means negligable.

Blacksmith Shop.

The two polishing and one emery wheel used for cultivator shovels and cultivator knives can be satisfactorily driven by one motor. The riveter, for riveting shovels, discs, etc., could be belted to this same shaft. The rated speed of the 10 H.P. motor needed for this set is 725 and it would probably be advisable to direct-connect the motor to the shaft. A change in pulleys on the driving shaft would have to be made.

Unless the machines can be made into a smaller group, it would be best to continue the countershaft, to which the trip hammers are at present belted, to the south end of the shop. To this shaft, should be belted the four trip hammers, the two bull dozers, the two punches, the small emery wheel in the tool-dressing room, and the short shaft in the stock room, to which last shaft are belted a bull dozer and shear. A 20 H.P. motor would pull them all.

The long main shaft could be uncoupled at the small punch and the north part taken down. The remaining part, to which are belted two punches, a drop hammer, a press, and a large bull dozer, should be driven by a 25 H.P. motor. The fan should also be belted to this shaft. However, some of these machines, as the bull dozer, punch, drop hammer, and fan, consume considerable power and could be driven to ad-

vantage by single motors. This would necessitate the grouping of the remaining machines and an inertia wheel would have to be furnished for the drop hammer. But if the fan is ever used at night for blast purposes, it might be advisable to drive it by a 5 H.P. motor. This fan furnishes blast for both the blacksmith and plow shops and, if a motor in one department should give out, the other department would still have the blast and would not be delayed.

Machine Shop.

Utilizing the present system of belting and shafting in this shop, two motors had better be used; a 15 H.P. on the first floor for operating the machines on the first floor, in the tool room and the room underneath, and a 5 H.P. for operating the second and third floors (not including the tool room). Both motors would have to be belted to the driving shafts. By so equiping the shop, the long shaft, which has long furnished power for this department and which lies under the blacksmith shop, can be taken down, and its constant power consumption be eliminated.

Plow Shop.

Four motors will be installed to drive this depart-

ment. The set of six emery wheels alongside the east wall will be driven by a 7-1/2 H.P. motor. The main shaft will be divided near the middle and all machines, belted to the south end, including an emery wheel, two Bradley cushioned hammers, a drop hammer, an emery wheel for grinding drills, a punch, and a drill press will be pulled by a 25 H.P. motor. As the load from these machines comes on all at once, a fly wheel will probably be necessary. The north end of the shaft will be connected by belt to a 10 H.P. motor. The machines belted to this shaft are all small and are only used at intervals. The plow polishing room can best be driven from one shaft, rather than take power from three sources, as is the case at present. A 50 H.P. motor would be required to run this and it should be coupled direct to the shaft. This shaft would drive the three polishing wheels, the two grindstones, the heavy, rapidly-revolving emery wheel and the hoisting apparatus, used in the tempering tank.

Wood Shop.

The main shaft of this department might be driven satisfactorily from the engine, but as the engine room is at present crowded and as the generators would have to be installed here, it is considered best to operate it with a 35 H.P. motor. The counter shaft in the adjoining room will

require a 20 H.P. motor. This does not include the planer, which will be driven separately by a 15 H.P. motor. The planer might be driven by the counter shaft but a 50 H.P. motor would then be required and, as the planer runs at intervals the motor would be running at a low efficiency and hence a needless loss would result. Equipping the shop with these motors eliminatesthe needless loss in the heavy belt between the two shafts.

Warehouse Machine Shop.

Electrical transmission would cause a greater saving in this department than in any other. Power is conveyed to this department by means of a shaft 235 feet long, lying in a damp tunnel. Five motors should be installed here. The emery and polishing wheels, used for grinding and polishing discs, should be driven by a 15 H.P. motor. The small machines in the basement should be driven by a 7-1/2 H.P. motor. A 10 H.P. motor should be belted to a short length of counter shaft and the two elevators driven from this. The gang punch, in the north room of shop, should be driven by a 3 H.P. motor and the 60 foot shaft taken down. The "Foster" shaft, 90 feet long, should also be taken down. And a 5 H.P. motor used to drive the machine.. 5 H.P. is high but more machines are likely to be added here and 5 H.P. will easily cover them all.

The motors suggested for installation are:

1 - 3 Horse-Power,
2 - 5 Horse-Power,
3 - 7.5 Horse-Power,
3 - 10 Horse-Power,
3 - 15 Horse-Power,
2 - 20 Horse-Power,
2 - 25 Horse-Power,
1 - 35 Horse-Power,
1 - 50 Horse-Power.

As the load is so variable, being very heavy in winter and light in summer, it seems advisable to install two separate generating units, one of 50 K.W. and one of 100 K.W. These would easily take care of the lighting of the works in addition to the power. The lighting would require about 35 K.W.

The estimate of the cost of motors and generators is as follows:

Motors.

Number.	H.P.	Price of one.	
1	3	at $141.00	$141.00
2	5	at 156.00	312.00
3	7.5	at 180.00	540.00
3	10	at 272.00	816.00
3	15	at 293.00	879.00
2	20	at 404.00	808.00
2	25	at 435.00	870.00
1	35	at 583.00	583.00
1	50	at 660.00	660.00
18	285.5		$5609.00

Generators.

Number.	K.W.	Price.
1	100	$1375.
1	50	825.
2	150	$2200.

Cost of Motors and Generators ....$7809.00.

These are fair average prices but will vary with the market. It is probable that, on competitive bid, they might be reduced ten percent or to $7000.00. (This includes cost of bases of machines, standard pulleys and automatic starters.) This figure is still high as several of the motors have been installed on the assumption that more power will be required in the future.

This estimate is for generating units and motors only; to this must be added the cost of wiring, fuses, switchboards, cut-outs, etc. These extras would cost in the neighborhood of $500. This makes the total cost of installation $7,500. The transportation and installation would make the figures run up somewhat higher, but the value of shafting, belting, bearings, etc., which would be thrown out of use by electrical installation, and which could be afterwards disposed of, would just about balance this "freight item."

As a considerable amount of shafting and bearings can be taken out, the amount of oil necessary for lubrication will be diminished. But this will not be taken into account. It will also be assumed that the number of men necessary to look after the satisfactory operation of the plant will remain the same. We will now consider the probable saving, due to electrical transmission, in a year's time.

As the same boiler will be used, we will consider the boiler efficiency to remain the same. The efficiency of

the plant from engine indicated horse-power to machines, as computed under the head of "engine trials," on page 52 of this thesis, is 36 percent. A fair average of the efficiency of a plant when electrically driven is 60 percent. This allows for engine loss, generator loss, motor loss, loss in shafting and also a drop of pressure due to resistance in the line.

The coal for the Scotch marine boiler for the day's test was 7707 pounds. The boiler was used for power purposes only, the exhaust being used for heating, as usual. 7707 pounds is high as the coal burned during the slack season is considerably less. Consider 6000 pounds, or 3 tons, as a fair average during the year. The price of coal used is $2.60, which includes the transportation. To this must be added the cost of handling at the plant, which would probably amount to $.40 per ton under the present aggravated conditions. Consequently the cost per ton at the boiler will amount to $3.00. Assuming three hundred and ten working days in a year, the cost of coal to furnish power under the present system is $2790.00.

The saving in percent would be $\frac{(60 - 36)\ 100}{60} = 40$. The saving in coal consumption for one year would be .40 x 3 x 310 = 372 tons, which cost $1116.00. From this must be subtracted the interest and depreciation on the capital invested. It is very evident that, since a great

many of the belts and shafts now installed, would be removed, the total depreciation and repairs on that which remains would not be as great as it is in the plant at the present time. This reduction in depreciation and repairs must be credited to the new installation. As a consequence, an allowance of 12 percent for interest, depreciation and repairs for the new installation, over and above the gain spoken of, must be considered a fair estimate. This amounts to $840.00, making the total saving for one year, $276.00.

Following are some of the advantage of the electrical over the "shafting and belting" method of transmission, in addition to those previously mentioned:

(1) The engine need not be stopped for belt repairs in the shops, thus obviating the necessity of delaying all hands and consequently the output.

(2) Any department can work over time separately. The engine has often been run over time to operate the elevators in the warehouse alone, a large loss from the long shafts resulting.

(3) Machines|can be placed in any position and in any location, thus facilitating the handling of the material.

(4) In case of accident to one dynamo, the other can be used, thus continuing the work. In extreme case of accidents to both dynamos, the feeders of the Janesville

Electric Company are just outside and could be made use of.

(5) Power could easily be furnished shop extensions.

(6) The Company could do its own lighting, which would result in a great saving.

(7) An accident to a motor or shaft would delay one machine or one part of a department only.

(8) A greater variation in speed could be obtained, and, in some machines driven individually, this is very desirable.

(9) Grouping of machines would give room for benches, trucking and piling of material.

Appendix I.

Determination of motor losses.

The main motor losses to be determined were the C^2R losses, of both the field and armature. The resistances of these parts were found by passing a current through each separately and noting the ammeter and voltmeter readings in each circuit. The average of a number of readings were taken, and the resistance calculated from "Ohm's Law," where the resistance is equal to the electrical pressure divided by the current flowing. After having found the armature and field resistances, it was necessary, in order to find the proper current to substitute in the loss formula, to run the motor at speeds corresponding to those at which it was run when connected to the machines in the shop. The motor was connected in circuit with the University's "Northern Generator." When working the motor a number of different field currents were employed. It was therefore necessary to maintain the field current at the different values and to duplicate the motor speeds under each. The desired speeds were obtained by means of regulating the pressure in the armature circuit. This regulation was accomplished by inserting a water rheostat in series with the circuit, while the field regulation was secured by means of a resistance-box placed

in series with its field coil. The armature current readings were recorded at these different speeds, the field current remaining constant. These values squared and multiplied by the armature resistance give the motor armature losses. The load current squared and multiplied by the armature resistance gives the load losses. The field currents squared and multiplied by the resistance of the field give the field losses. The sum of these losses subtracted from the apparant power is a measure of the energy imparted by the motor to the machine.

The resistance values as calculated were 163.7 ohms for the field and .432 ohms for the armature. The values of the field currents which were used in calculating the losses will be found on the table under the heading of motor readings.

Appendix No. I.

Table of field losses, in watts, for given field currents ranging from .85 to one ampere.

Field current.	Loss in watts.
1.	163.7
0.98	157.2
0.97	153.9
0.96	150.6
0.95	147.3
0.94	144.7
0.93	141.6
0.92	138.5
0.90	132.6
0.89	129.3
0.88	126.4
0.87	123.2
0.86	120.9
0.85	117.9

Appendix II.

The instruments which were likely to vary in their readings were tested in the laboratories of the University of Wisconsin by comparison with the proper standards. These instruments are:

1. Ammeter No. 5750,
2. Ammeter No. 6258,
3. Voltmeter No. 4450,
4. Indicator spring No. 5479,
5. Indicator spring No. 5480,
6. Thermometers,
7. Scales,
8. Steam Gage.

Ammeters No. 5750 and 6258 were tested by comparison with millivoltmeter, which was adjusted so that it read for each respectively between (0 - 1) and (0 - 75). Voltmeter No. 4450 was tested by comparison with Standard voltmeter No. 302.

The indicator springs no. 5479 and 5480 were tested by comparing the pressures indicated by the deflection of the pointer attached to the spring of the indicator, with a mercury column to which the instrument had communication.

The thermometers were tested by immersion in water

brought up to the boiling point; account being taken of atmospheric pressure.

The scales used in weighing the feed water were balanced at zero.

The steam gauge was calibrated by comparison with the Crosby steam gauge tester.

The instruments were all found to be correct with the exception of the steam gauge, which was reading 2-1/2 pounds too high. This necessitated the subtraction of that amount from all B.P. readings.

Data and curves relative to the calibration of the instruments can be found following on the next page.

Calibration of Electrical Instruments.

Weston ammeter No. 5750 tested by comparison with Weston direct reading laboratory standard millivoltmeter No. 294.

Reading between 0 and 1.

No. 5750	No. 294
.14	.1
.24	.2
.34	.3
.435	.4
.525	.5
.625	.6
.725	.7
.825	.8
.925	.9
1.03	1.0
1.13	1.1

A correction of .01 must be added to all readings of No. 294.

Calibration of Electrical Instruments.- Continued.

Weston ammeter No. 6258 tested by comparison with Weston direct reading laboratory standard millivoltmeter No. 294.

Readings between 0 and 75.

No. 294	No. 6258
1	.75
2	1.65
3	2.6
4	3.7
5	4.75
6	5.7
7	6.7
8	7.75
9	8.85
10	9.6
11	10.75
12	11.75
13	12.75
14	13.8
15	14.7
20	19.6
25	24.7
30	29.75
35	34.8
40	39.75
45	44.75
50	49.75
55	55.5
60	60.5
65	65.5
70	

Calibration of Indicator Springs.

Indicator No. 5480.

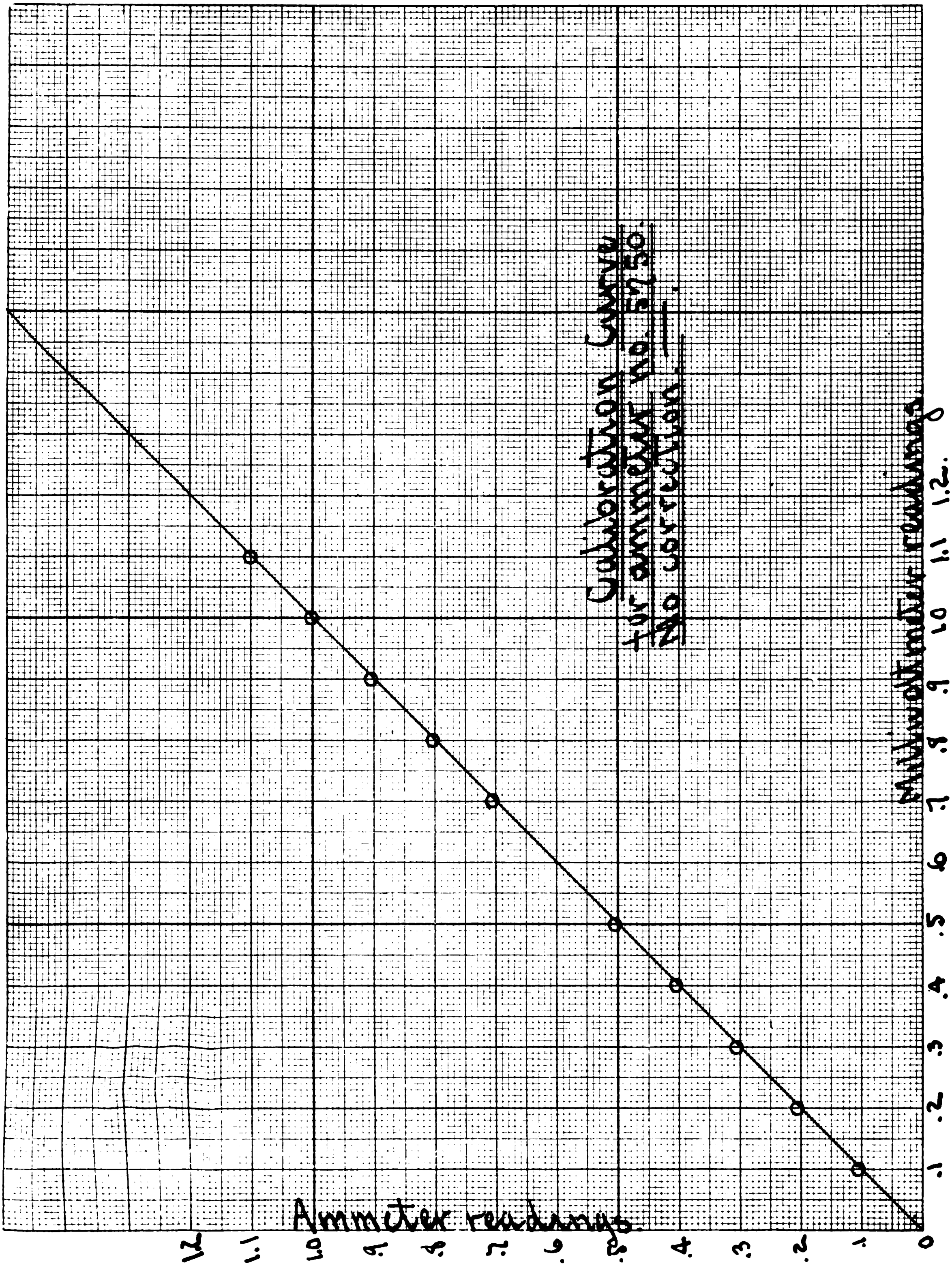
Weight mercury column		Deflection of springs
inches	pounds	
20	9.8	11
40	18.6	21.5
60	29.4	29.5
80	39.2	40.
100.5	49.24	49.5
121.5	59.535	59.
141.	69.09	69.
158.	77.42	78.5
188.	92.12	93-3/4

Indicator No. 5479.

Weight mercury column		Deflection of springs
inches	pounds	
20	9.8	10
40	18.6	20
60	29.4	29.5
80	39.2	40.66
100.5	49.24	50.
119.	58.31	58.
130.5	63.945	63.5
141.	69.09	69.5

Calibration of Steam Gauge.

Increasing.				Decreasing.			
Diff. 4.1#	Gauge .9#	Weights # standard	equtt.	Gauge 10	Diff. 5	Weights # 5	
5	15.	2#	10	15.5	5.5	2#	10
5	25.	4#	20	24.5	4.5	4#	20
3	43.	8#	40	44.5	4.5	8#	40
3	63.	12#	60	64.	4.	12#	60
2.5	82.5	16#	80	82.5	2.5	16#	80
2.5	102.5	20#	100	103.	2.	20#	100
2.5	122.25	24#	120	122.5	2.5	24#	120
2.	142.	28#	140	142.	2.	28#	140



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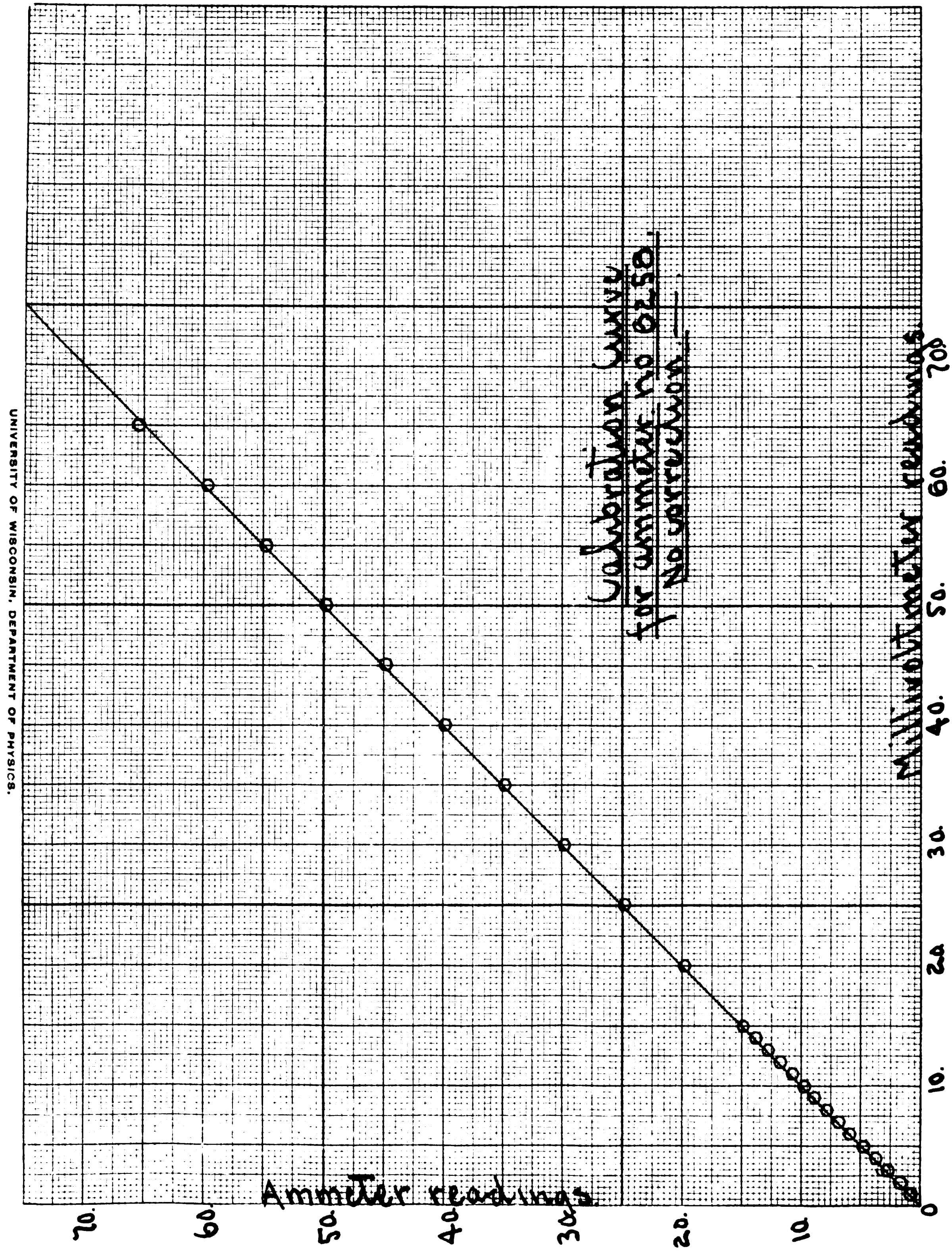
Calibration curve
for ammeter no 0250.
No correction.
Millivoltmeter readings
0
10.
20.
30.
40.
50.
60.
70.
Ammeter readings
10.
20.
30.
40.
50.
60.
70.
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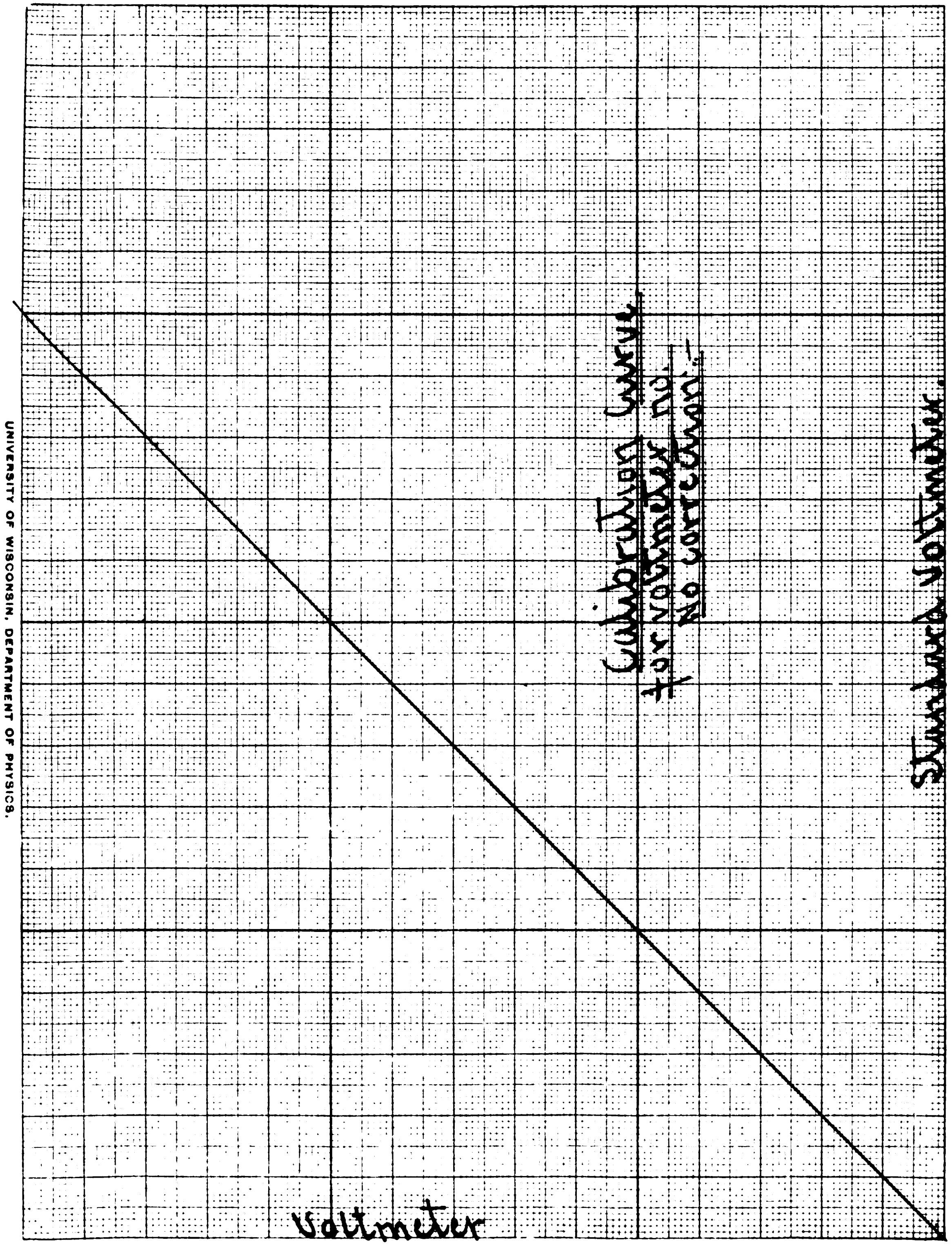
Calibration curve
for voltmeter no.
No correction.
Standard voltmeter.
Voltmeter
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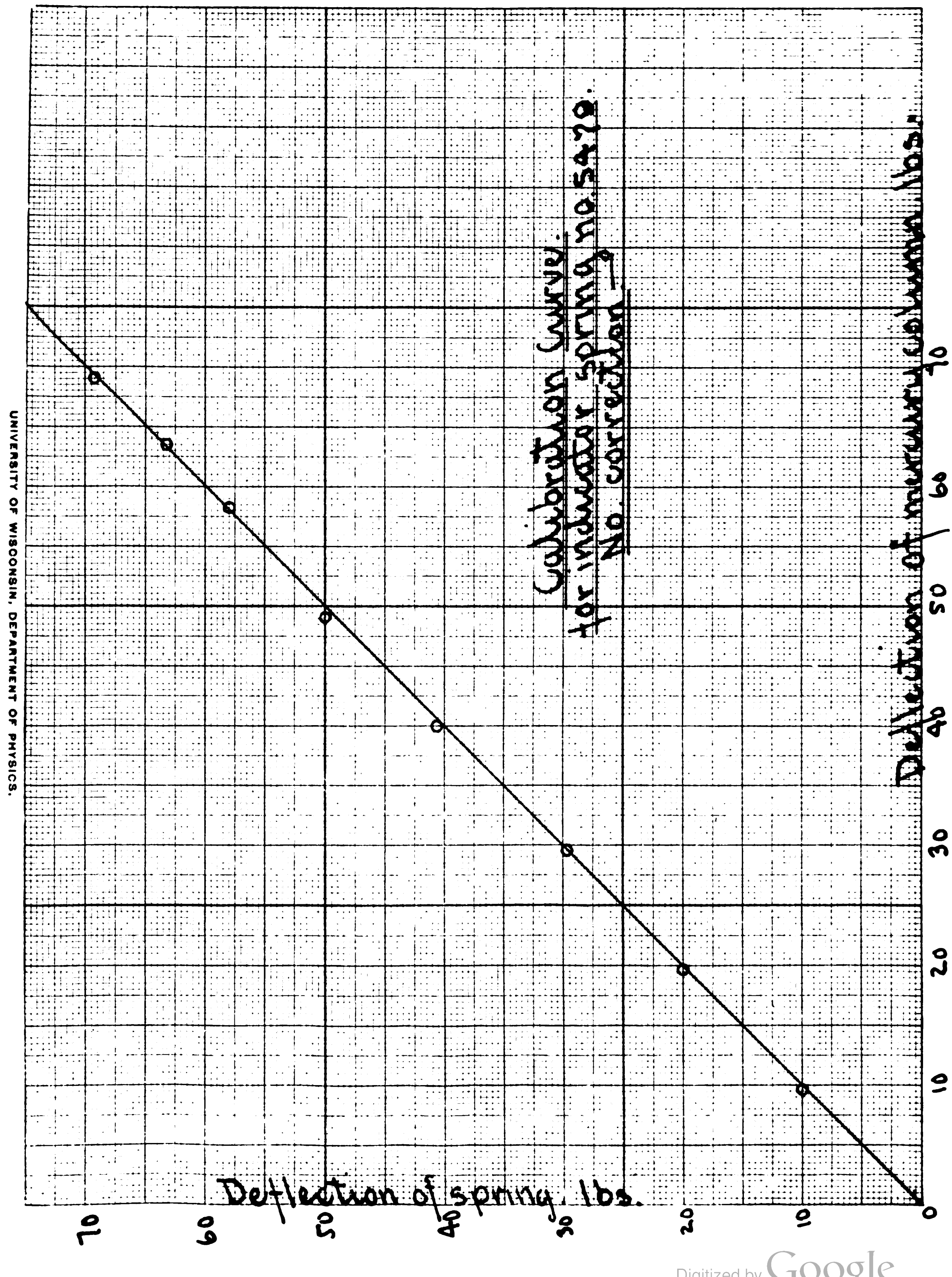
Calibration Curve.
for indicator spring no. 5429.
No correction —
Deflection of mercury column lbs.
0
10
20
30
40
50
60
70
Deflection of spring. lbs.
0
10
20
30
40
50
60
70
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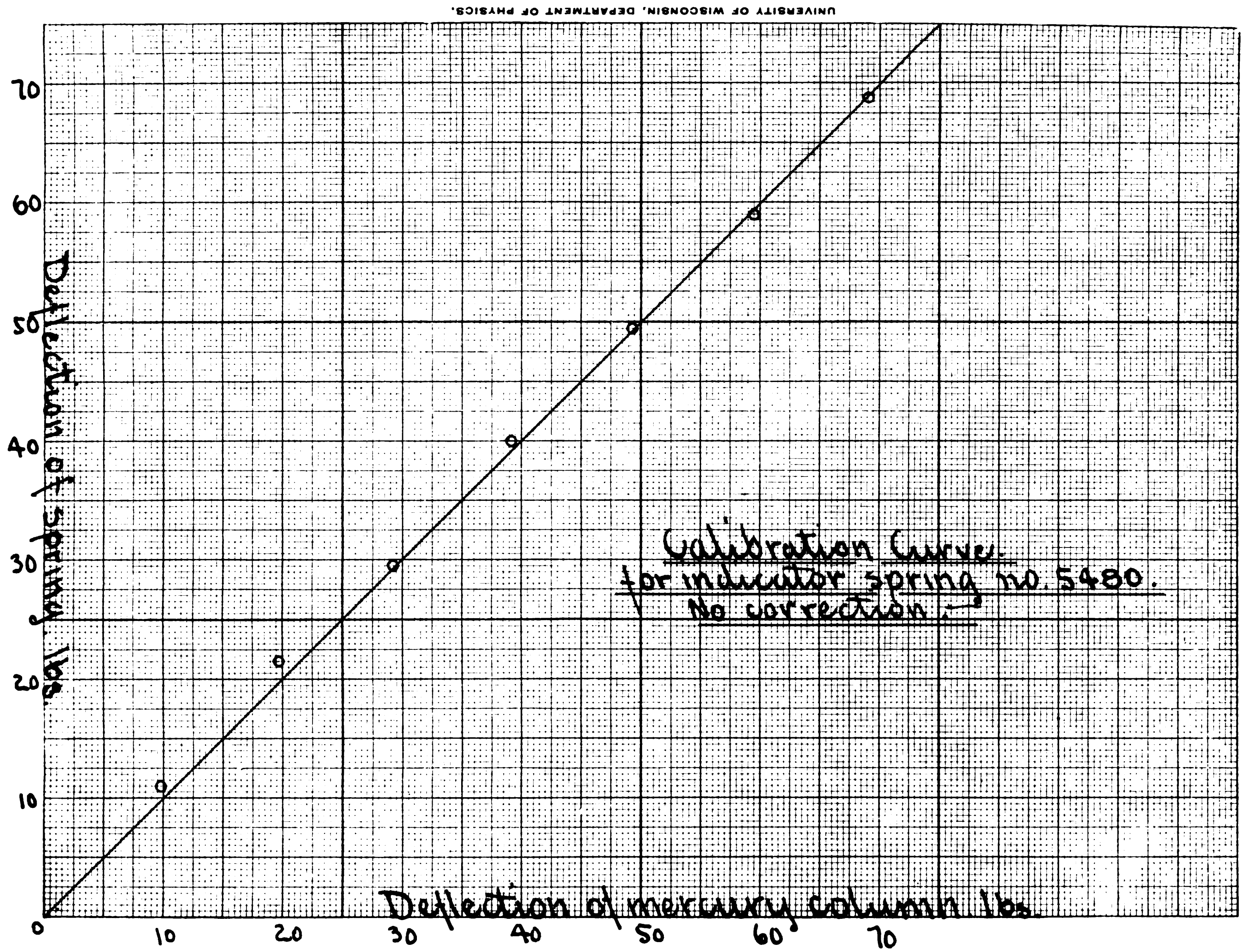

Calibration Curve.
for indicator spring no. 5480.
No correction.

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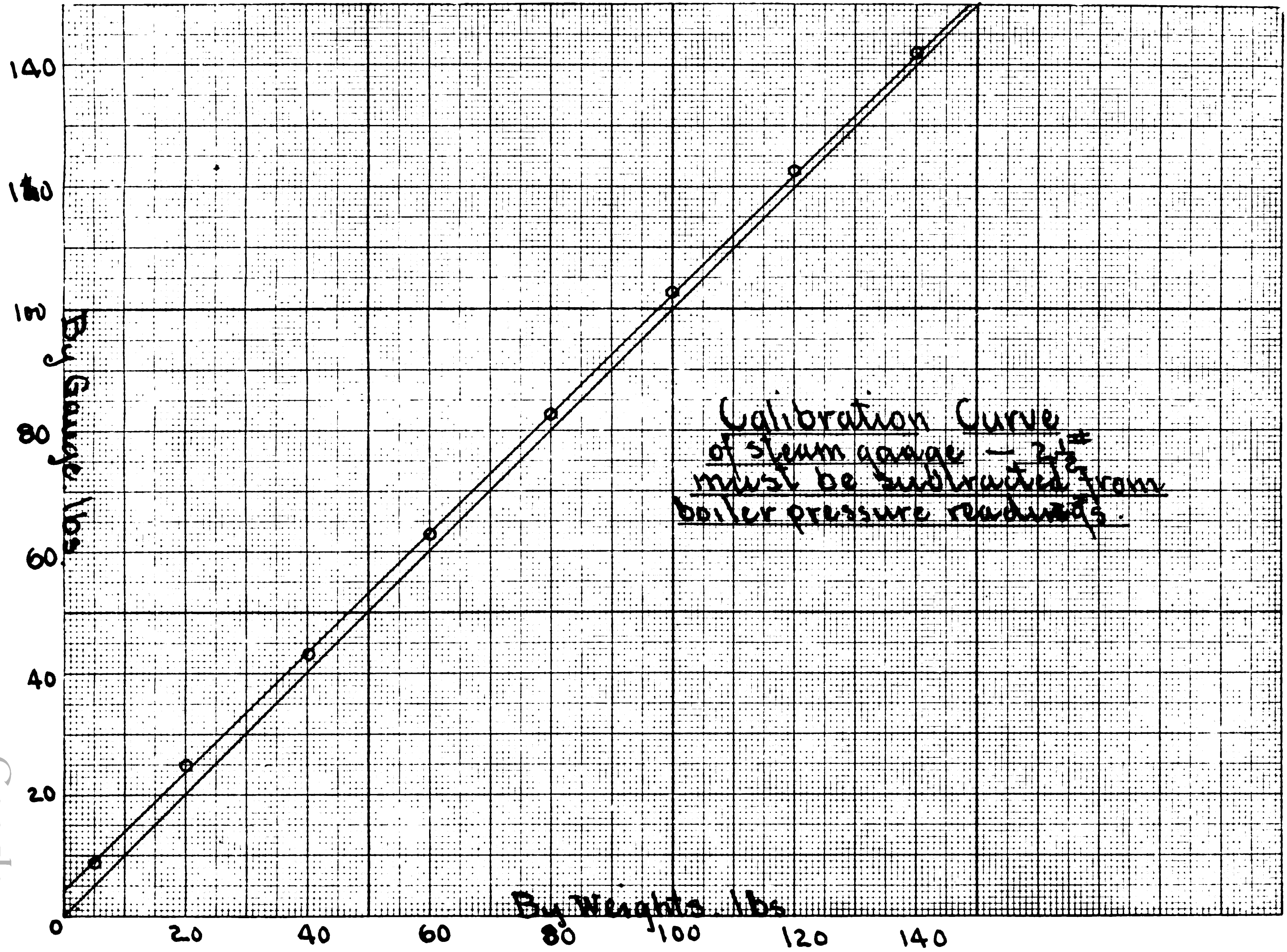

Calibration Curve of steam gauge — $2\frac{1}{2}$# must be subtracted from boiler pressure readings.

APPROVED:

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